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HW-74094 VOL3
Page 1

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HAZARDS SUMMARY REPORT

VOLUME 3 - DESCRIPTION OF THE 100-B, 100-C, 100-D, 100-DR, 100-F and 100-H PRODUCTION REACTOR PLANTS

Prepared by

The Staff of the Irradiation Processing Department [redacted]

April 1, 1963

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HANFORD ATOMIC PRODUCTS OPERATION
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TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED) Page

TABLE OF CONTENTS (CONTINUED)

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TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED) Page

LIST OF ILLUSTRATIONS

HAZARDS SUMMARY REPORT

VOLUME 3 - DESCRIPTION OF THE 100-B, 100-C, 100-D, 100-DR, 100-F AND 100-H PRODUCTION REACTOR PLANTS

I. INTRODUCTION

A. Purpose and Scope

The purpose of this Hazards Summary Report, HW-74094 Volume 3, is to present a comprehensive physical description of the 100-B, 100-C, 100-D, 100-DR, 100-F and 100-H Production Reactor Plants at Hanford. This volume is part of an over-all Hazards Summary Report, and complements Volumes 1 and 2. A similar Hazards Summary Report, HW-74095, is being issued for the 100-KE and 100-KW Production Reactor Plants at Hanford.

The term "Production Reactor Plant" is defined as a Hanford Production Reactor plus its associated water supply and effluent water disposal facilities.

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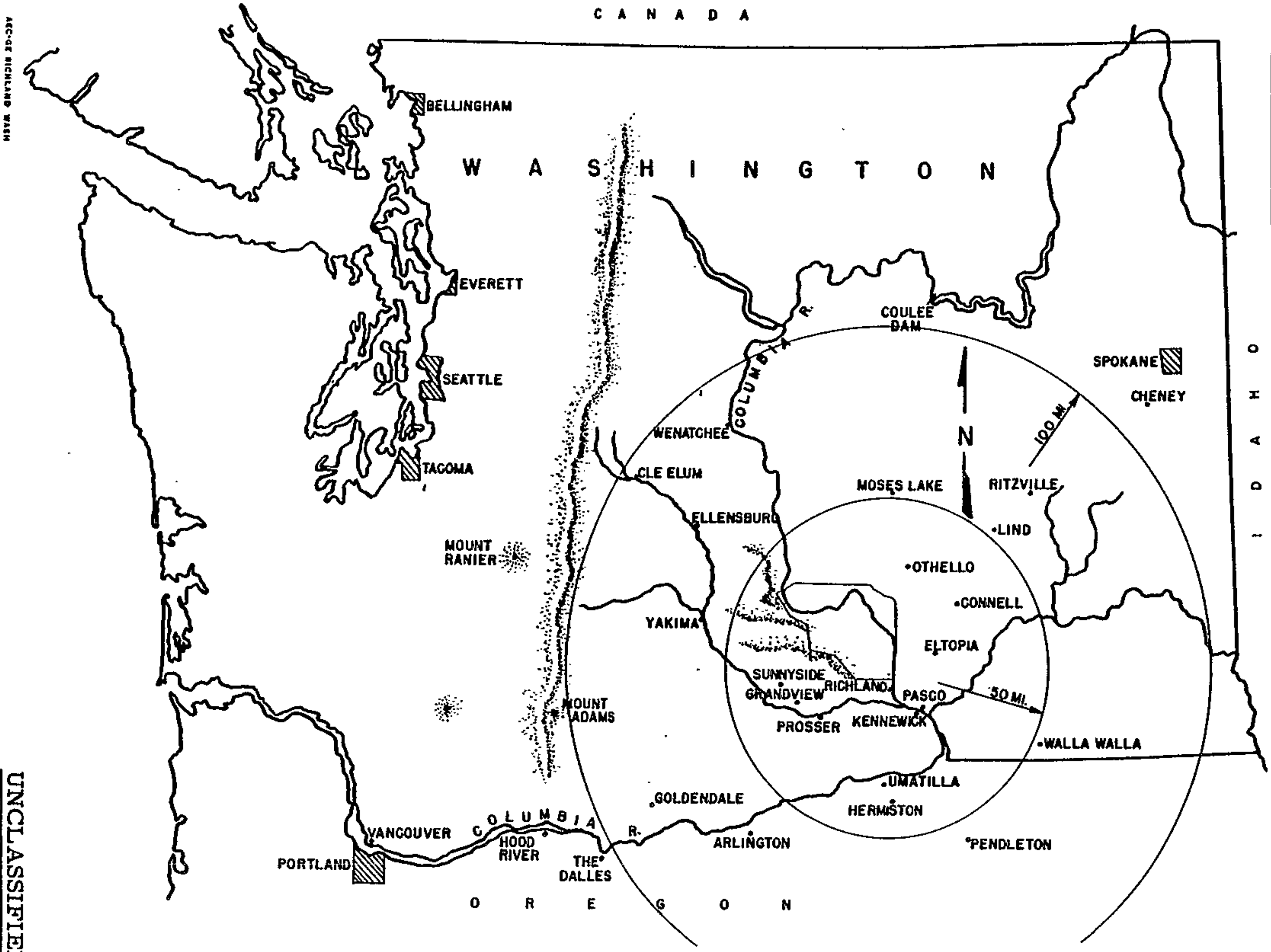

Figure II-1
Hanford Site Location

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II. SITE AND ENVIRONMENT

A. Geographic Location

The Hanford Atomic Products Operation is located in the south-central part of the State of Washington. Figure II-1 shows the location of the Hanford site, occupying approximately 600 square miles within the State. The Hanford site is bounded by the Columbia River to the north and east, Rattlesnake Mountain to the southwest, and Richland, Washington to the south. A controlled access zone, approximately 5 miles wide and 25 miles long, is maintained immediately north of the Columbia River.

B. Plant Layout

The plant layout of the Hanford site is shown in Figure II-2. The eight production reactor plants and the 100-N Reactor are located in the northern part of the site on a generally flat plateau 400 to 500 feet above mean sea level. The separations plants are located near the center of the site, and the fuel preparation and laboratory facilities are located near the southern boundary.

C. Reactor Areas

Each production reactor plant is located within a fenced, limited area, with access controlled and available only to authorized personnel.

As shown in Figure II-2, the 100-B Limited Area contains the 100-B and 100-C Production Reactor Plants; the 100-K Limited Area contains the 100-KE and 100-KW Production Reactor Plants, and the 100-D Limited Area contains the 100-D and 100-DR Production Reactor Plants. The 100-H and 100-F Production Reactor Plants are located within the 100-H and 100-F Limited Areas, respectively.

Typical limited areas are shown in Figure II-3 and II-4. Located within the limited areas are the processing, servicing, and administrative facilities. The nuclear reactors proper are located within the inner exclusion area.

D. Population Distribution

A graphical representation of the results of the 1960 census of the State of Washington is presented in Figure II-5.

E. Seismology

The Hanford area is in a region susceptible to earthquake damage from the active seismic zones of Western Washington, and from the seismic zone that includes the Walla Walla, Washington area. For building code purposes, the entire area east of the Cascade Mountains and most of the Rocky Mountains is classed as Zone 2 on the Seismic Probability Map.

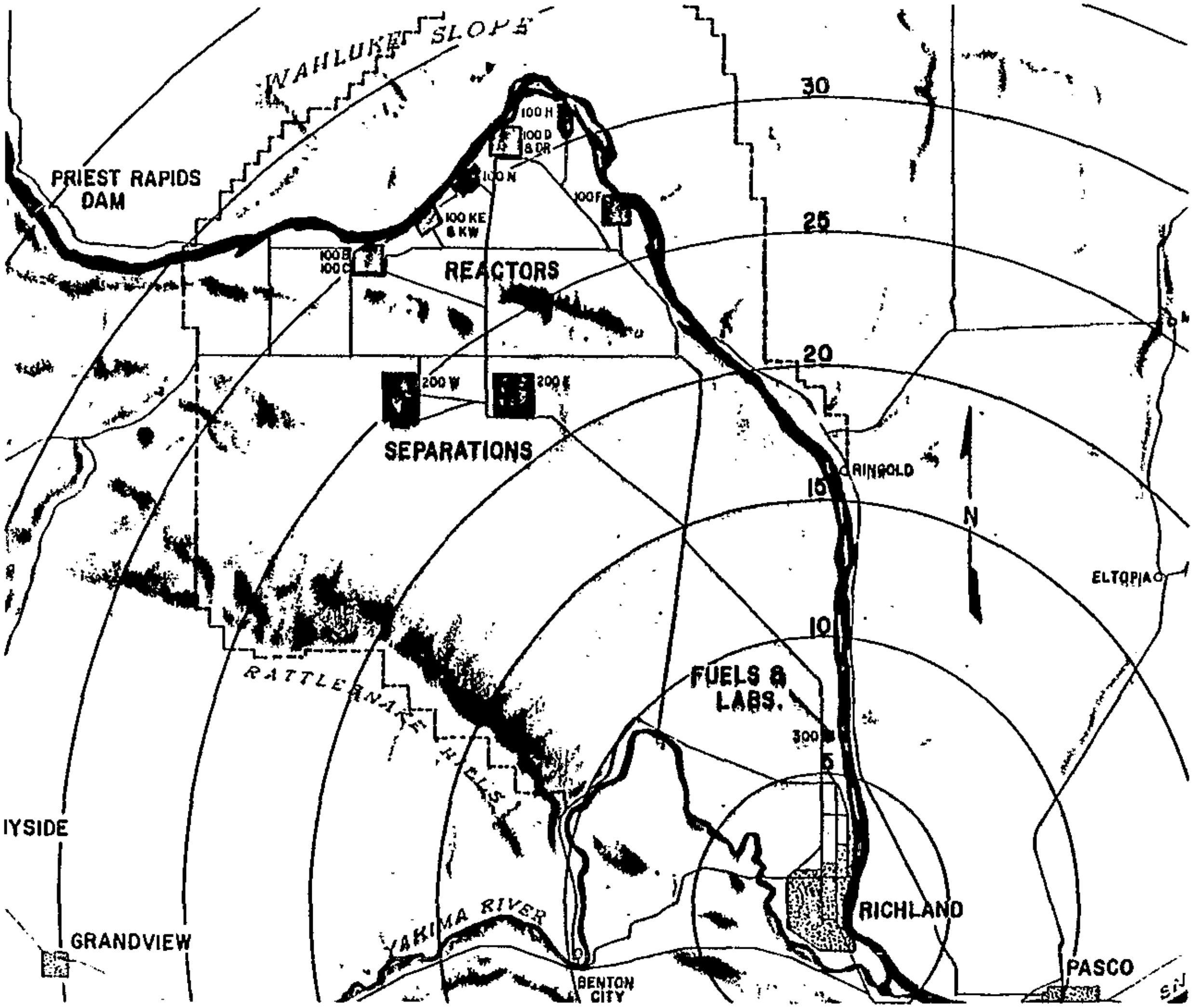

FIGURE II-2
Hanford Plant Layout

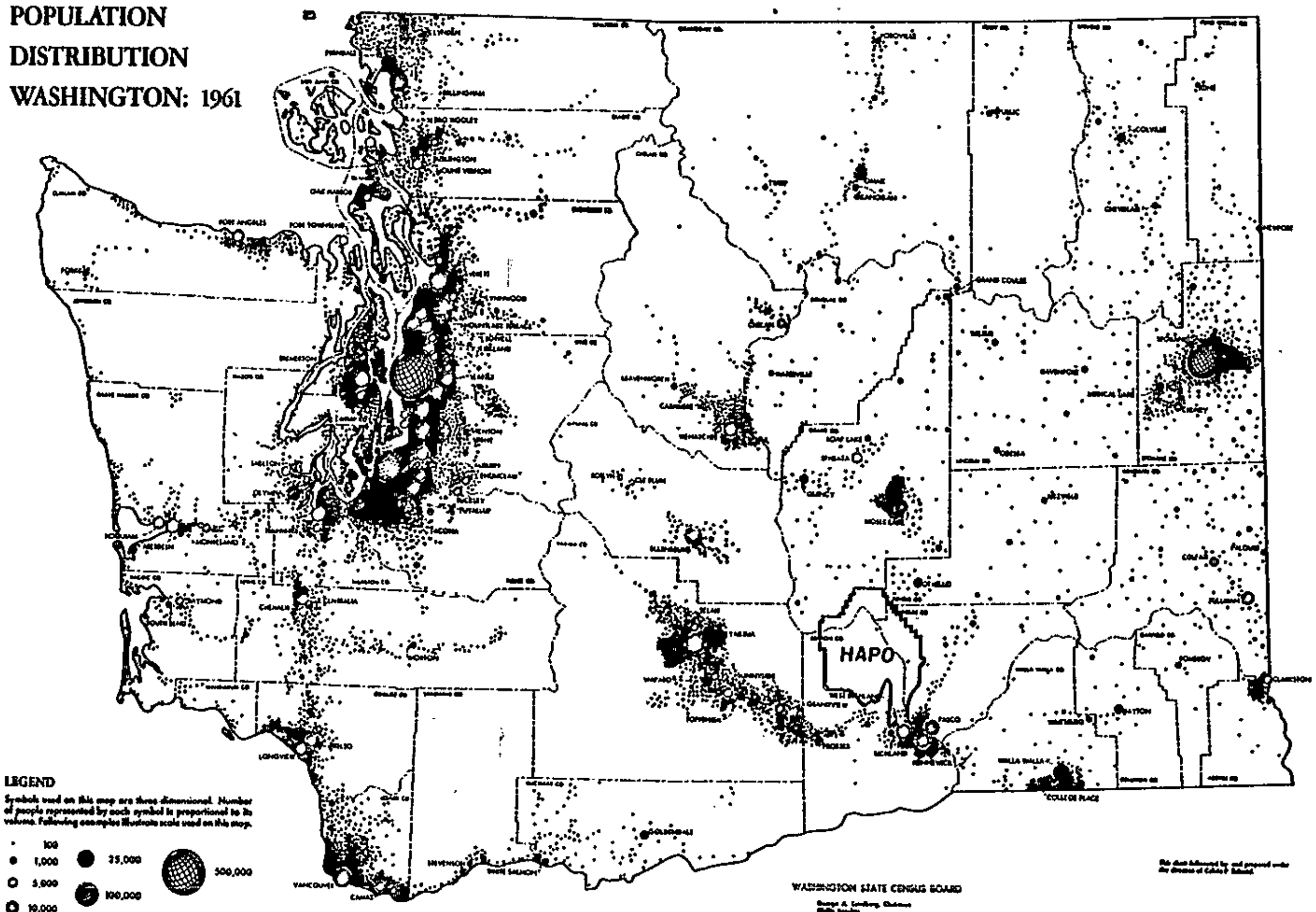

FIGURE II-5

Population Distribution in Washington State

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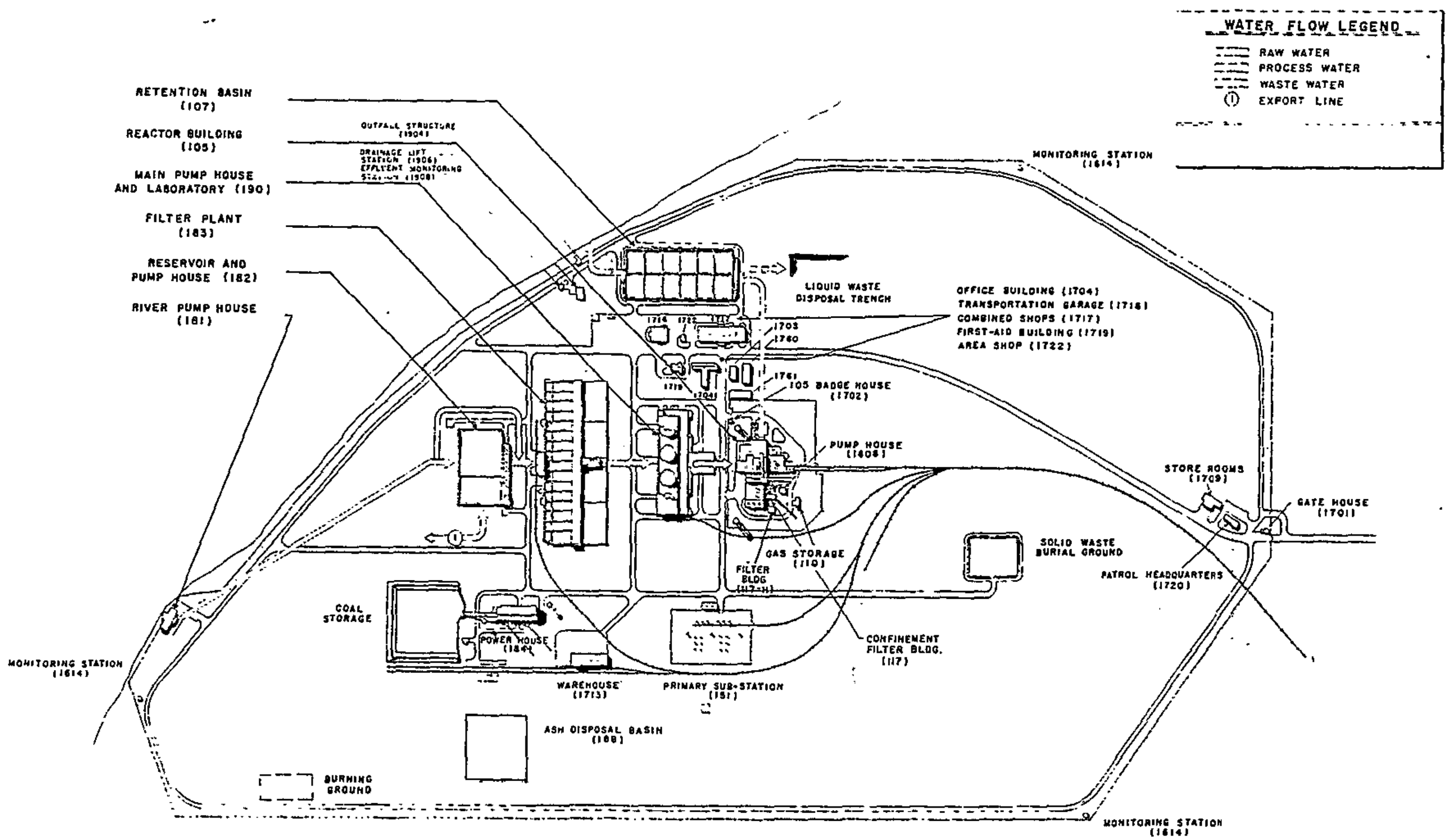

FIGURE II-3

Typical Limited Area for Single Production Reactor Plant

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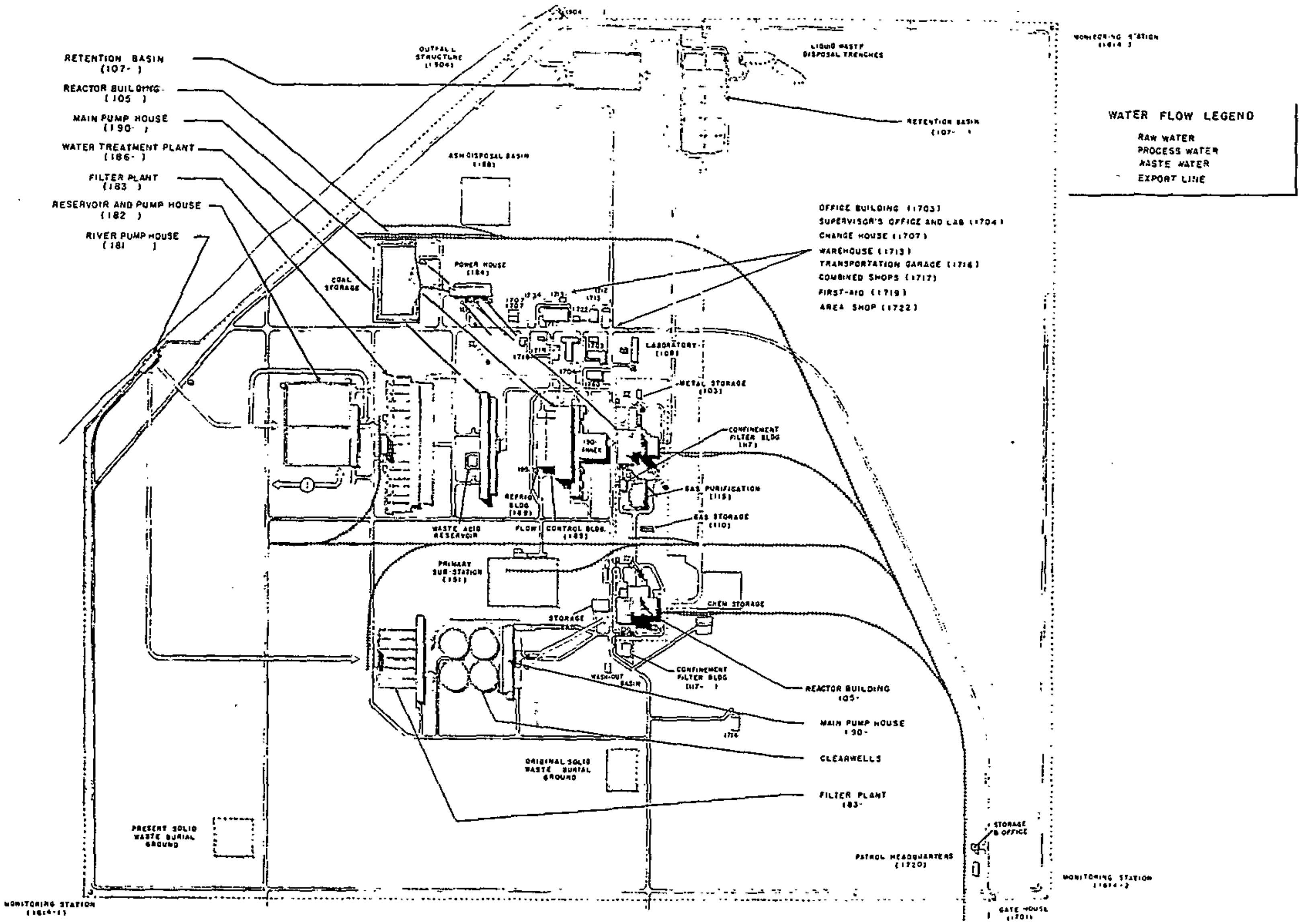

FIGURE II-4

Typical Limited Area
for Dual Production Reactor Plants

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No damaging earthquakes have ever been recorded in the immediate vicinity of the Hanford Plant during the 60 years of historical record. However, earthquakes causing moderate to severe damage have occurred in the Pacific Northwest. An earthquake in 1918 at Corfu, Washington, a number of minor shocks at Ellensburg, Washington in 1934 and at other times, and at Othello, Washington in 1957 imply an active zone along the north side of the Saddle Mountains to the north of the Hanford site.

The apparent intensities of earthquakes noticed in the vicinity of the Hanford Plant have not exceeded approximately IV of the Modified Mercalli (MM) Scale of 1931. This corresponds to a ground acceleration of about 0.01 g.

F. Meteorology

A meteorological unit is maintained at HAPO for the purposes of recording conditions and making forecasts, and of performing research and development pertinent to plant operation. The meteorological station is located adjacent to the 200-W Limited Area, approximately five miles south of the 100-B Limited Area, and is the principal source of local information.

Wind speeds (50-ft. level) at Hanford average 7.5 mph. June has the highest monthly average (9.0 mph), while December and January have the lowest (6.0 mph). High winds may occur at any time, but average speeds are lower in winter because of frequent, and sometimes extended, periods of stagnation between storms. Peak gusts of 40 mph or more occur on 74 days out of each 1000 while gusts of at least 50 mph have a frequency of 15 out of 1000 days.

The wind blows hardest from southwesterly directions, but most frequently (35 percent of the time) from the WNW and NW. The directions S-through-WSW have a combined frequency of 27 percent, but account for 71 percent of all average hourly speeds of 25 mph or more and 74 percent of daily peak gusts 40 mph or more. WNW and NW account for all but 7 percent of the remainder of such cases.

Thunderstorms occur on an average of 13 days per year with 85 percent of the total occurring during the months May-through-August. About 20 percent are associated with high wind (gusts to 40 mph or more) and a lesser percentage may be associated also with blowing dust, heavy rain or hail. Hurricanes apparently are unknown in this locality. Tornado funnels have been observed twice in 18 years, but no resulting damage has been reported.

The heaviest rain in 18 years amounted to 1.68 inches in 6 hours (October 1957) and the heaviest snow totaled 8 inches in 6-1/2 hours (December 1955). Analysis of the records shows that storms of this magnitude in 24 hours or less can be expected about 5 times in 100 years.

Figure II-6 summarizes other pertinent meteorological data, including relative humidty, temperature, and precipitation experience.

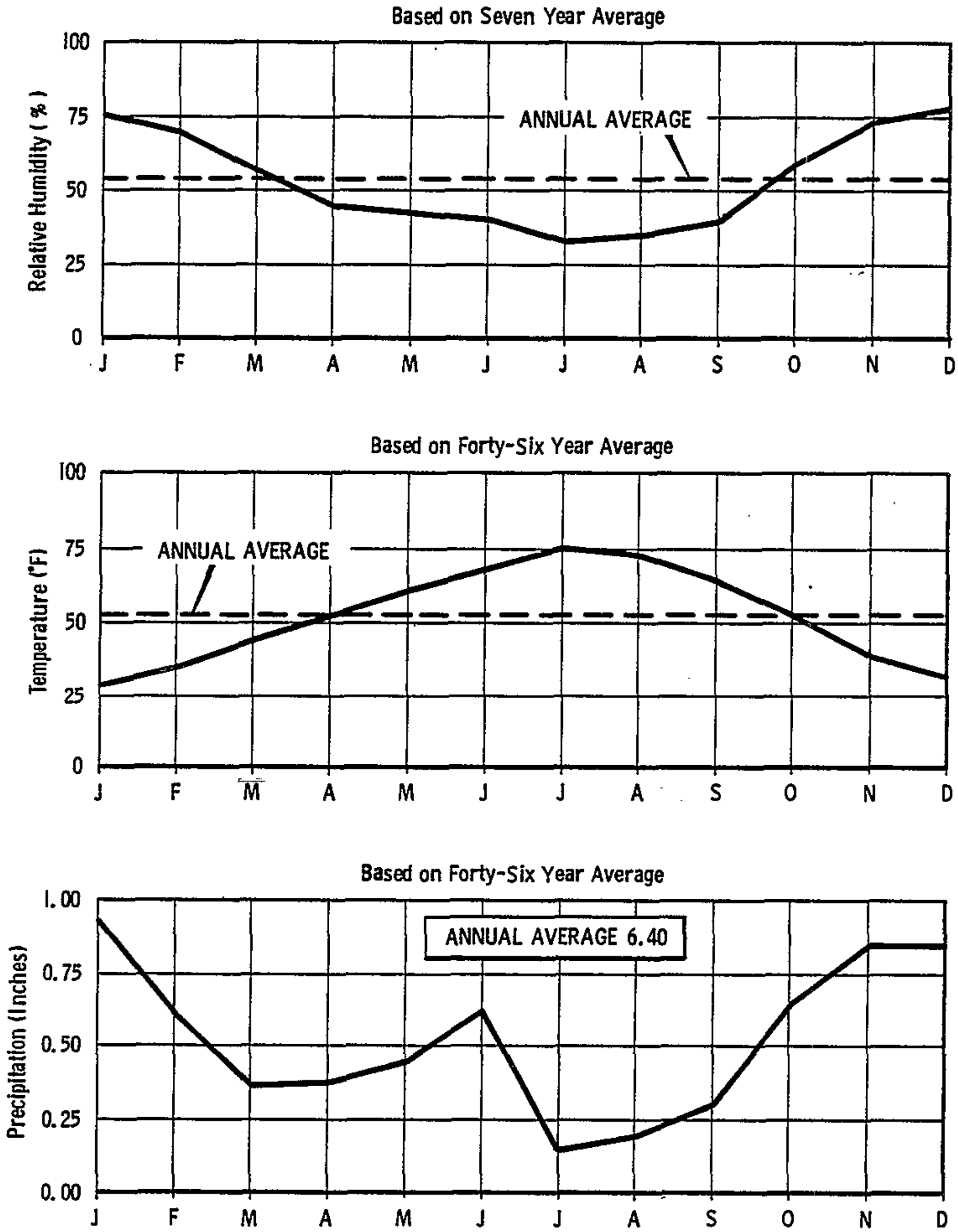

FIGURE II-6

Hanford Meteorological Data

G. Geology and Hydrology

There are three distinct geologic units beneath the production reactor plants: the glaciofluviatile sediments; the Ringold Formation; and the Columbia River Basalt. The Columbia River Basalt series forms the bedrock beneath the reactor areas and is generally compact, hard, and dense. The Ringold Formation, an extensive lacustrine and fluviatile deposit of sand, silt, gravel and clay, overlies and is largely conformable to the basalt. Unconformably overlying the Ringold Formation, to a maximum depth of 170 feet, is a deposit of outwash sands and gravels, referred to at Hanford as glaciofluviatile sediments. The coarse materials of this deposit are more abundant in the northwest section of the project, and grade into finer materials to the east and south.

The contour of the water table in the region underlying the production reactor plants reflects strongly the contact between the Ringold Formation and the glaciofluviatile sediments. The most rapid ground water movement rates have been noted in glaciofluviatile-filled channels incised in the Ringold sediments. Several of these ancient river channels are known to exist in the region of the production reactor plants.

The water table beneath the plants lies at an average depth of 100 feet and represents the upper boundary of the unconfined ground-water zone in this region. Figure II-7 is a contour map of the water table underlying the region of the plants. This map shows the general ground-water contour pattern, except for seasonal fluctuations which occur adjacent to the Columbia River in the late spring. The recharge of the ground water is normally from the highland areas to the south and southwest. A small amount of recharge comes from the retention basins and cribs located within the limited areas. These limited areas show up conspicuously on the contour map as isolated ground-water mounds along the river.

The permeability of the basalt series to water flows normal to their surfaces, is generally very low, particularly compared to the lateral permeability of the interflow zones. The ground waters within the basalt series, therefore, are quite separate and distinct from those in the post-basalt sediments. The material which makes up the Ringold Formation directly overlaying the basalt is either so fine grained or so poorly sorted that it has a relatively low permeability; generally this ranges from 10 to 1,000 gallons per day per square foot (gpd/ft^2). The glaciofluviatile sediments are coarse-grained and generally highly permeable; permeabilities range from 10,000 to 50,000 gpd/ft^2, or from 10 to as much as 5,000 times those of the Ringold Formation sediments.

The average field permeability of the sediments directly beneath the 100-F, 100-H and 100-D Areas is approximately 510 gpd/ft^2 and beneath 100-B Area, 1000 gpd/ft^2.

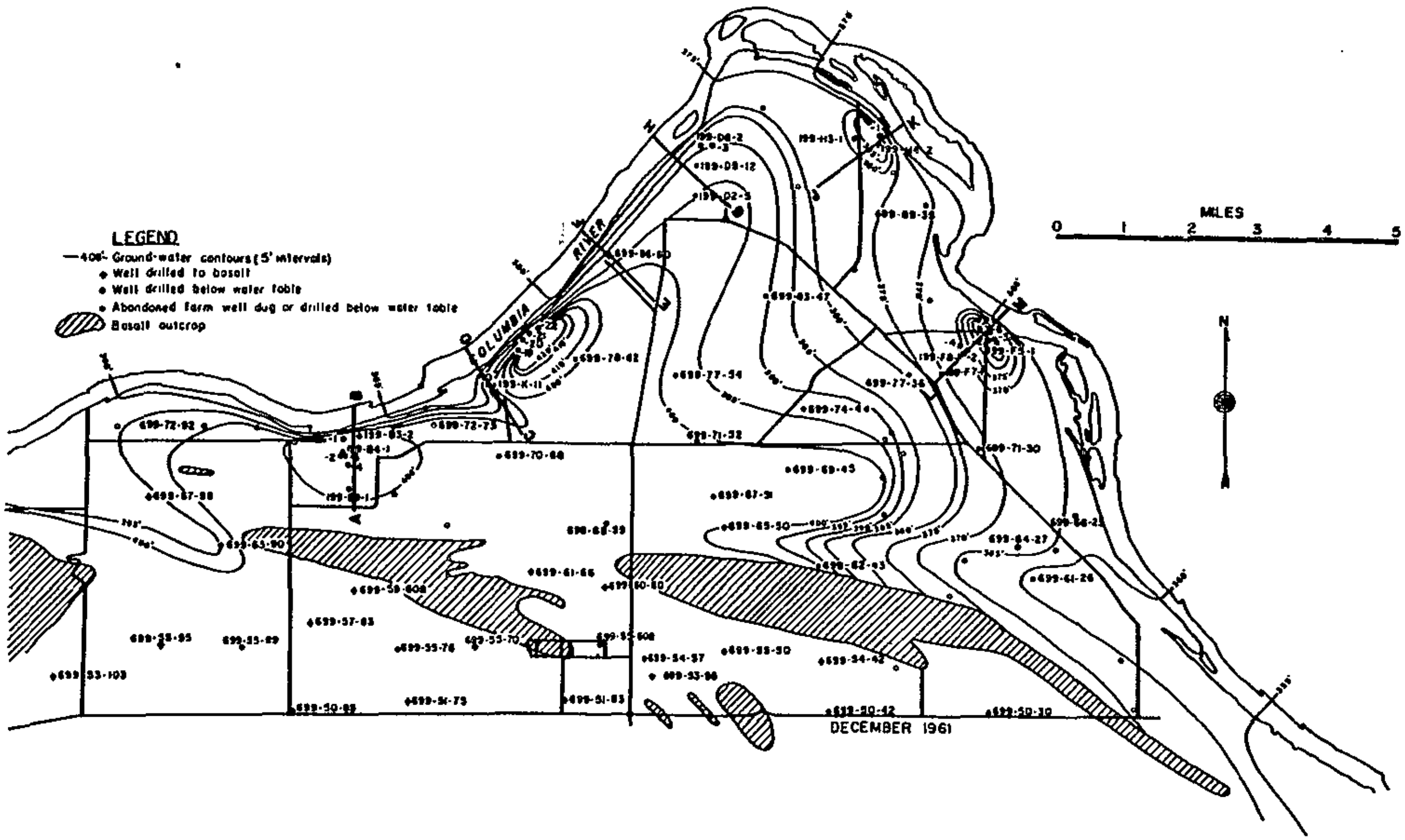

FIGURE II-7

Ground Water Contour Map of the Water Table Underlying the Region of the Hanford Reactor Areas

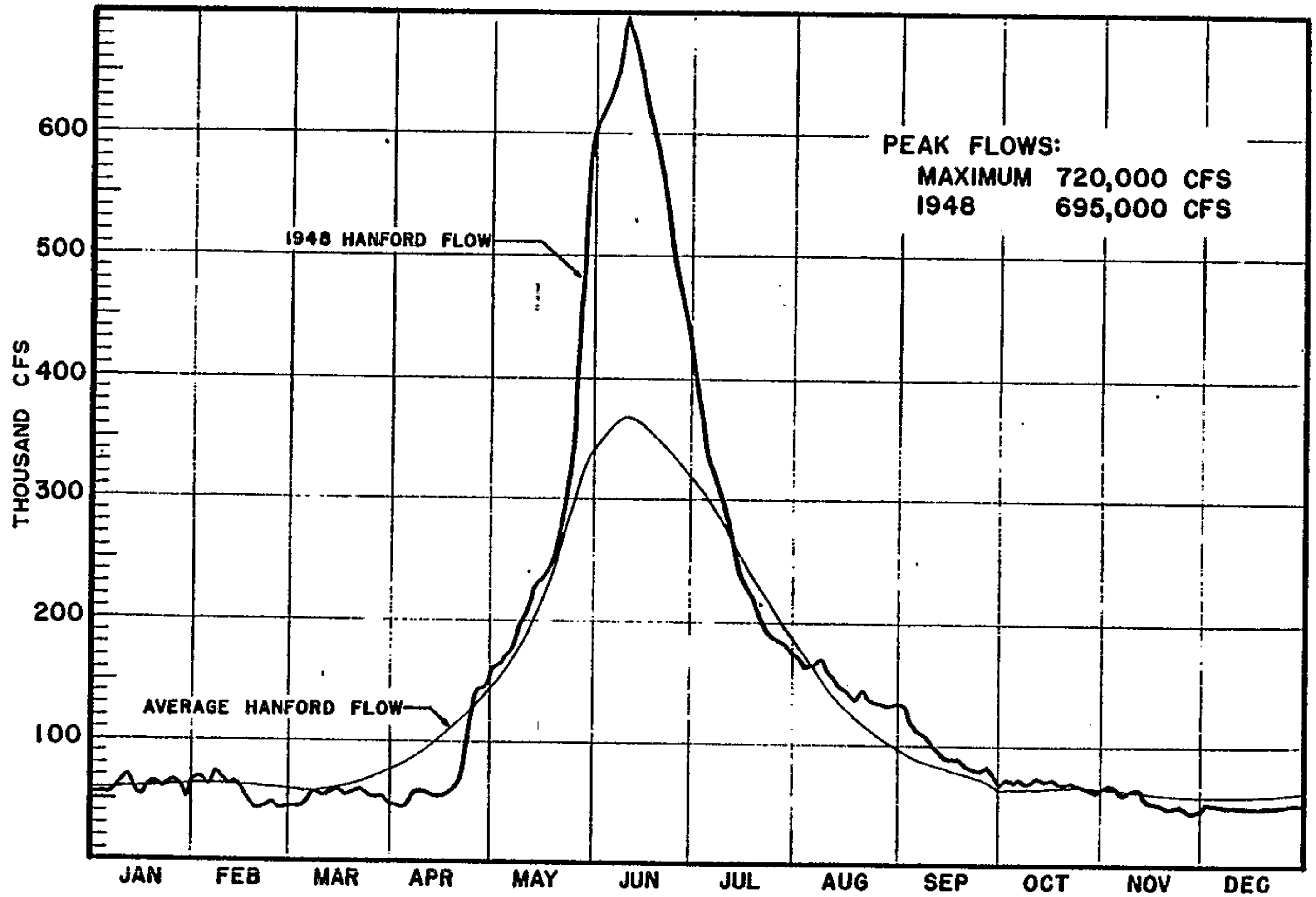

FIGURE II-8

Columbia River Flow at Hanford

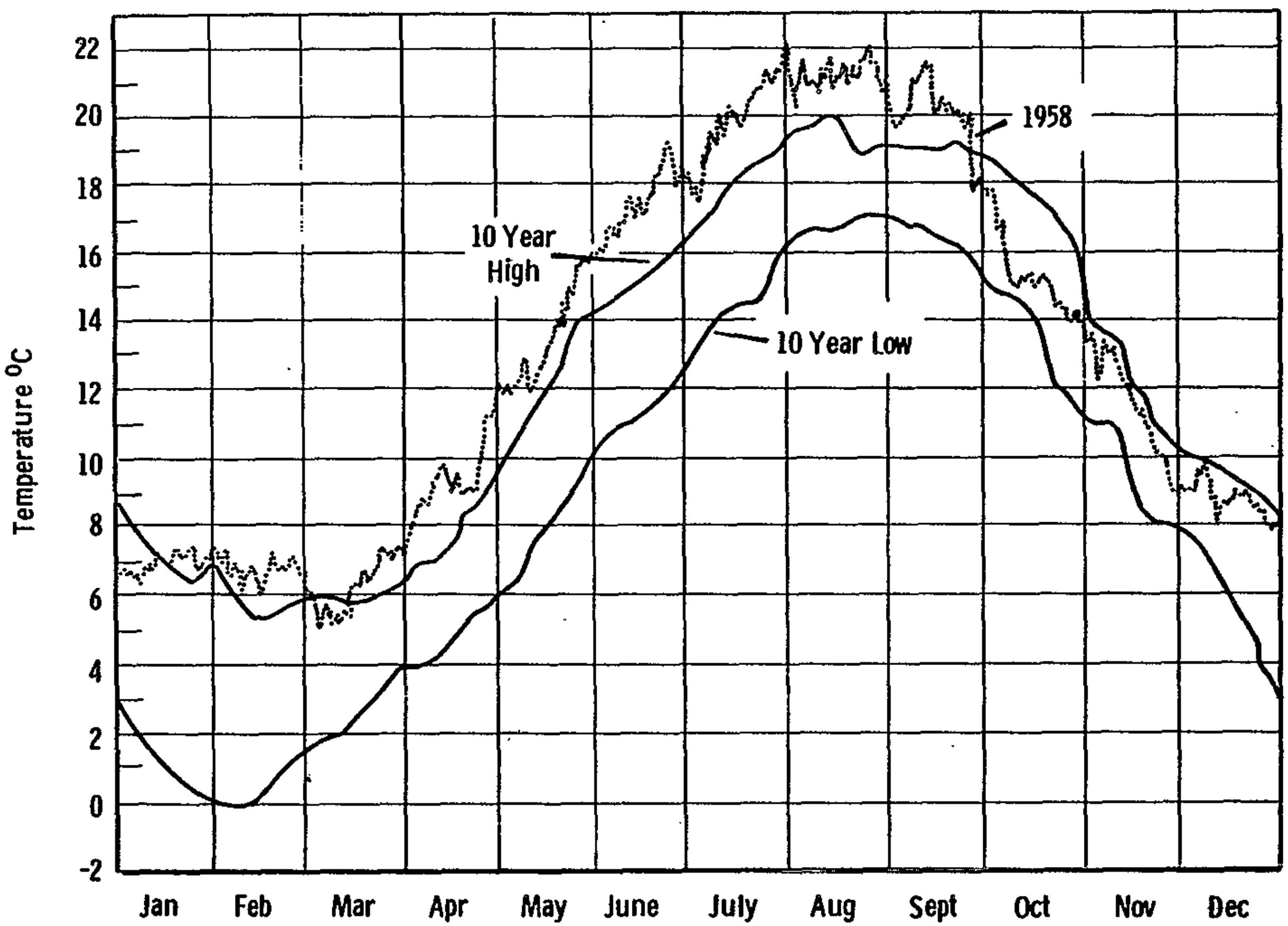

FIGURE II-9

Columbia River Temperature at Hanford

H. Columbia River

The Columbia River is the source of water for the Production Reactor Plants at Hanford. Five dams are located upstream, shown in Figure II-10, with Priest Rapids the nearest. Just north of the Hanford site, the River drains an area about twice the size of the State of Pennsylvania or approximately 95,000 square miles. Its flow rate varies through the year as shown graphically in Figure II-8. The water is exceptionally pure which makes this source of coolant especially valuable to the reactor plants. The river temperature varies, as shown in Figure II-9, which is of interest to the reactor plant operations.

I. Electrical Power Sources

The source of electric power for the Hanford site is the Bonneville Power Administration's (BPA) tranamission and distribution system. Figure II-10 presents the BPA system configuration in simplified form.

Electric power is supplied to the Midway Substation, which is the central source of distribution for the Hanford site, by three 230-KV lines from Grand Coulee Dam, two from Bonneville, and one each from the Big Eddy Substation and Columbia Substation, and three from Priest Rapids Dam. Figure II-11 illustrates the bus arrangement of the BPA Midway Substation and the connections and routing of the three 230-KV lines serving the reactor areas.

Through switching, power is supplied to three 230 KV-buses at Midway, which in turn distribute power to the Hanford system. The Hanford system, supplying power to each of the production reactor plants, consists of three 230 kv overhead transmission lines in a center tapped loop configuration.

Hanford Lines No. 1 and No. 2 were erected as a part of original plant construction. Wooden poles and cross-arms were used for all structures. Tangent structures were of the two-pole, H-frame type and three and four poles were used at corner and station structures. Line conductors were 636 thousand-circular-mils (MCM) aluminum-clad-steel-reinforced (ACSR), and overhead static and buried counterpoise wires, two of each, were used for lightning protection on the entire loop. A third line, with steel towers and 795 MCM ACSR conductors, was installed in 1957 to connect Midway to the 230-KV loop between 100-KW and 100-KE. No counterpoise or overhead static wires have been provided for the third line. As reactor plants were added, new line sections and substation modifications were required. These line sections and substations utilized steel structures.

Primary protection from phase faults in the transmission lines is provided by directional comparison carrier relaying. Backup protection is provided by reactance-type distance relays. Protection from ground phase faults is provided by product-type directional relays. Differential current relaying is

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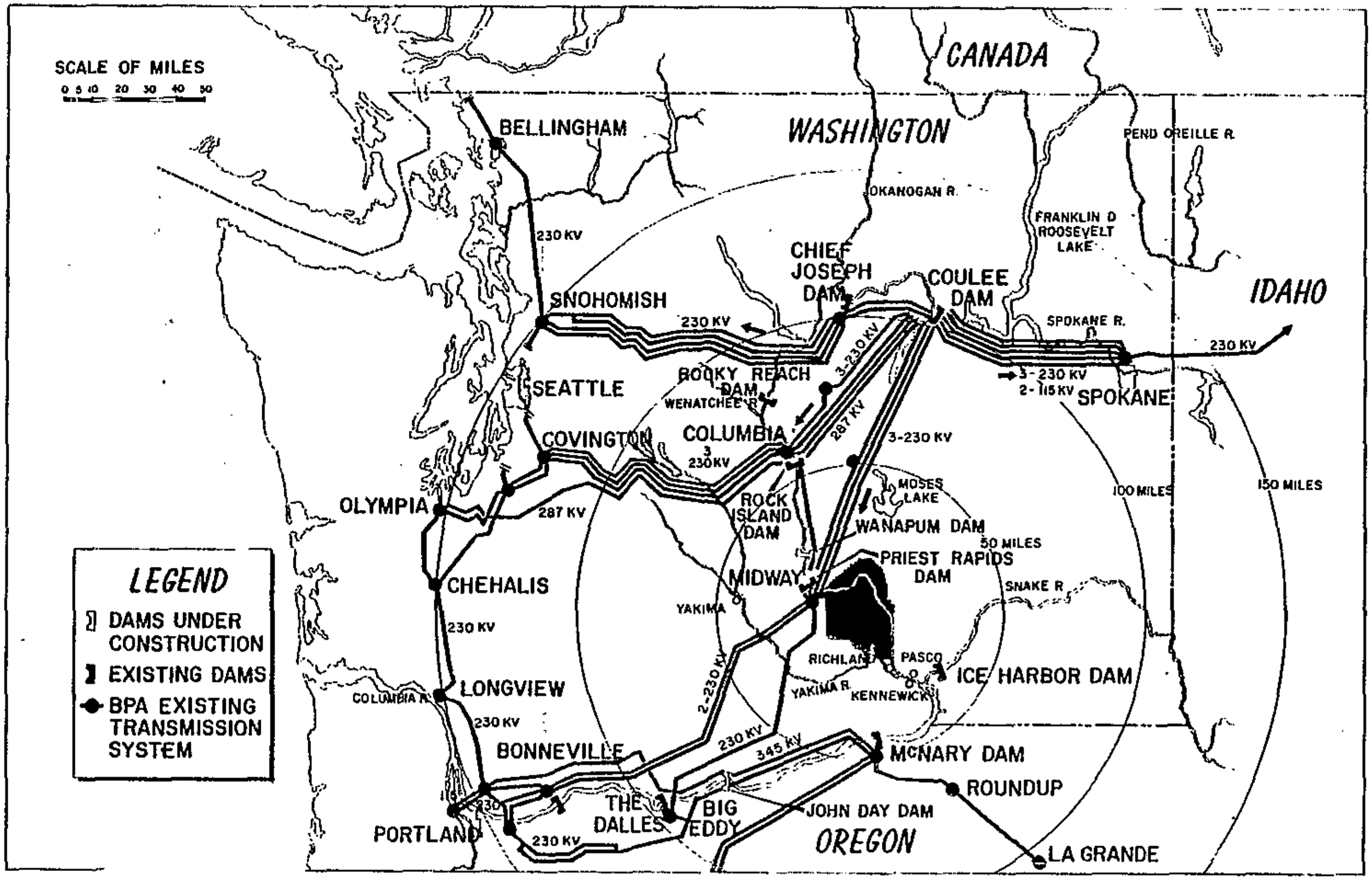

FIGURE II-10

BPA Main Grid Transmission System

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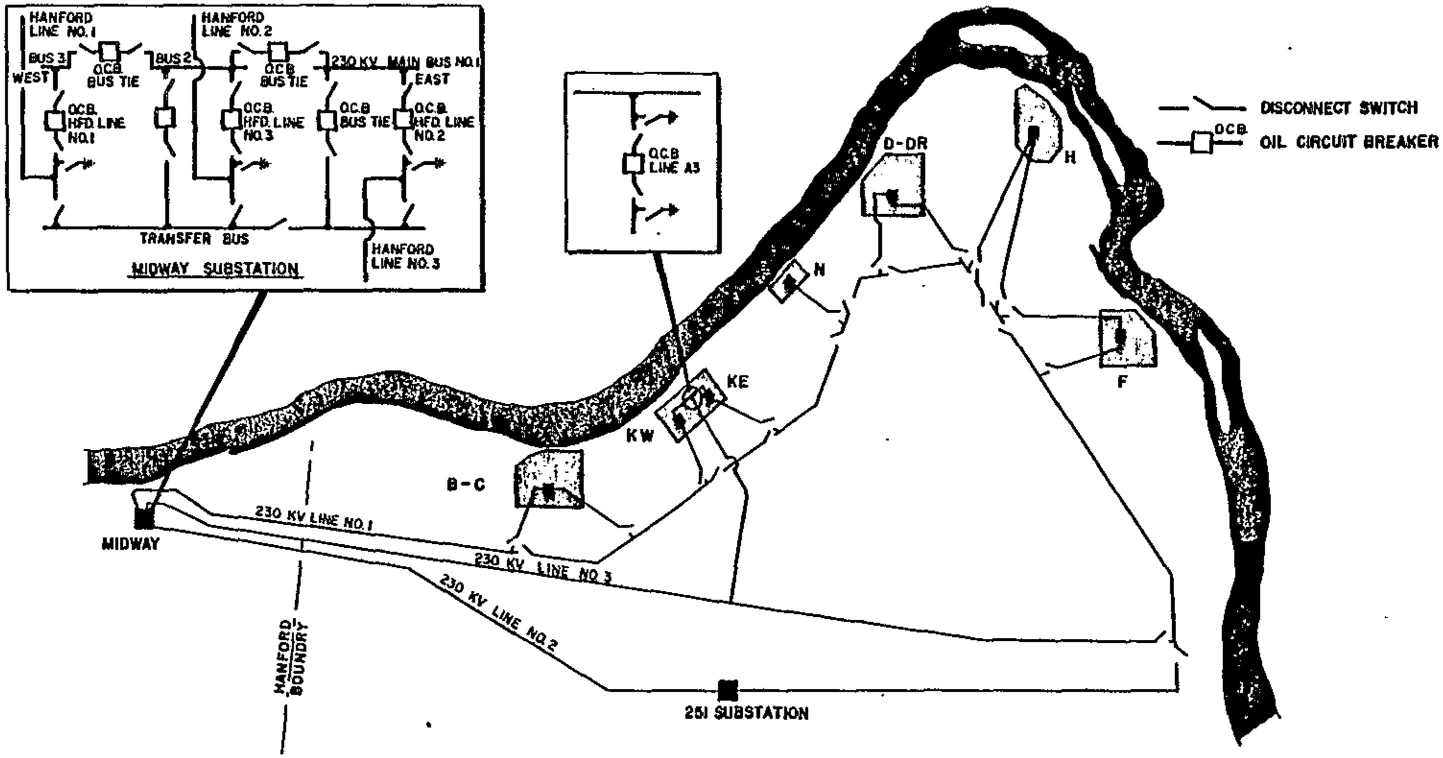

FIGURE II-11

HAPO Electrical Distribution System

used on main transformers and 230-KV bus sections in each area substation. In addition to the protective relays at Midway, the circuit breakers in the Hanford lines are equipped for one automatic reclosure, four seconds after line fault tripping. The short circuit interrupting rating of the circuit breakers at the 151-B, KW and KE Buildings is 10,000-MVA. At the 151-D, H and F Buildings, the nameplate rating is 2,500-and 3,000-MVA. The available short circuit capacity at Midway is approximately 8,000-MVA, symmetrical.

III. WATER PLANT AND AUXILIARIES

Approximately ninety-four percent of the heat produced in a reactor is generated in the uranium fuels, the remainder in the graphite moderator. The rate of removal of this heat is critical to the safe operation of the reactor. An adequate continuous supply of cooling water can avoid a fuel meltdown and the consequential release of fission products.

Three systems for maintaining an adequate flow of coolant have been provided in each of the Reactor Plants. They can be described as an electrically-powered pumping system designated the Primary Coolant System, a steam-powered pumping system designated the Secondary Coolant System, and a dual-system of elevated water tanks at each reactor combined with a pipe line interconnecting all of the Reactor Plants designated the Last Ditch System. A detailed description of each of the systems follows.

A. Primary Coolant System

The primary cooling system will provide adequate reactor cooling during all phases of operation and shutdown. The system is designed so that it does not require any help from either of the other two systems in order to provide the required amount of coolant. Electrical power is the energy source for operating this system. The sequence of operations is shown schematically in Figure III-1.

1. River Pump House - 181 Building

Cooling water for the Hanford production reactor plants is drawn from the Columbia River by means of pumps located in river pump houses known as "181 Buildings." There is one river pump house in each of the four limited areas. In the 100-B and 100-D Limited Areas, each pump house services two reactors.

All pumps are vertical deepwell types with submerged bowls and impellers. The bottom of the bowls is approximately eleven feet below the normal low-water level of the river.

The water intake channel in front of the pump houses has been dredged and lined with rock and concrete to form a forebay. River water enters the pump house deepwell through traveling screens which prevent entrance of fish and debris.

The 100-B and 100-D river pump houses each contain two deepwells separated by concrete walls, but are interconnected to allow water to flow from one deepwell into another in case of intake screen blockage.

Transformer stations located at the 181 Buildings reduce the line voltage of 13.8 kv to 2300 volts and supply a minimum of two 2300 v buses in the building. The bus ties are normally open so that a dual power supply is available at each building with each bus carrying approximately one-half the load.

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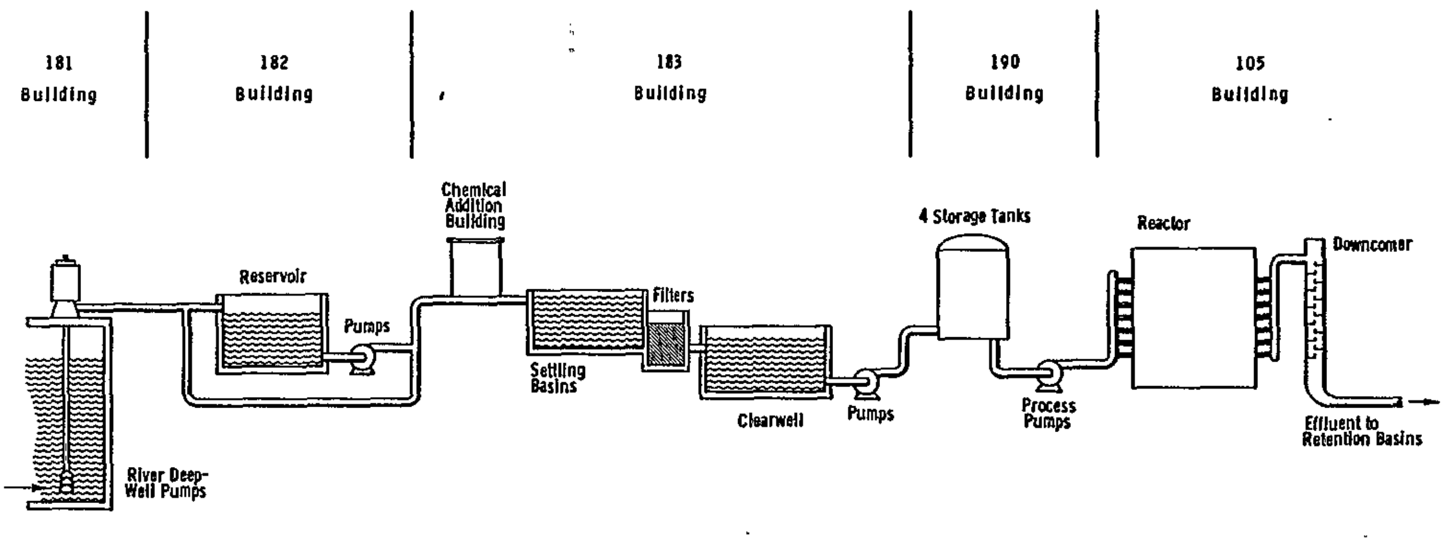

FIGURE III-1

Water Flow for a Typical Production Reactor Plant

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The electric motors used for driving the pumps are three-phase, 2300 volts, squirrel cage, induction motors with manual controls. A remote control system has also been provided for the river pumps in the 181-B and the 181-D Buildings. The pumps in the 181-B Building are controlled from the filter plant head house in the 183-C Building and the pumps in the 181-D Building are controlled from the 183-D Building head house.

The number and size of pumps at each of the river pump houses is shown below:

RIVER WATER PUMPS

Area Pump House	ELECTRICALLY DRIVEN				Water System	STEAM DRIVEN			
	No. of Pumps	Capacity gal/min	Head feet	Motor Rating HP		No. of Pumps	Capacity gal/min	Head feet	Turbine Rating HP
181-B	8	10,500	180	600	Process	2	7,500	150	400
	2	10,500	150	450	Export				
181-C	2	16,500	150	900	Process				
	11	10,000	150	450	Process				
	1	10,000	150	450	Export				
181-D	9	13,000	220	900	Process	2	7,500	150	400
	1	10,000	150	450	Export				
181-DR	5	13,800	185	900	Process				
181-F	10	10,000	150	450	Process	3	7,500	150	400
181-H	9	10,500	180	600	Process	3	7,500	150	400

The steam turbine driven pumps are installed in the 181 Building river pump houses to provide emergency backup pumping capacity should the normal electric power be interrupted. There are occasions when one or two steam driven pumps are used continuously for several days while an electrically driven pump is out-of-service for maintenance or repair.

There are two carbon steel pipe lines from the river pump discharge headers to each of the 183-B, D, DR, F and H filter plant head houses. One of the two pipe lines at 183-B, D, F and H is also connected to the respective 182 reservoir. In addition to this reservoir connection, there is also a separate 30-inch line from the river pump headers to the reservoirs at the 182-B, D, F and H Buildings. Water can be pumped to the reservoirs through either the supply line to the 183 Building or the separate 30-inch line. The main pipe lines between the 181 and the 183 Buildings are combinations of 36-inch, 42-inch, and 48-inch lines.

The 183-C head house is supplied by three 48-inch carbon steel lines from a common header at the river pump house.

2. Reservoir and Pump House - 182 Building

The purpose of the reservoir and pump house is to provide reserve water for reactor cooling, condenser water for the steam condensers, and raw water for the Separations Plants.

There is one 182 Building in each of the 100-B, D, F, and H Limited Areas. Each building contains an inlet house, an open concrete reservoir, and a pump room. The reservoir capacity at the 100-B, D, and F Areas is 25,000,000 gallons each. The 100-H reservoir has a capacity of 10,000,000 gallons. The water level in the reservoir is controlled by a float switch which operates a control valve in the inlet house.

Prior to plant modifications performed in 1956 - 1957 under Project CG-558, the reservoirs were used as the principal water supply source for the filter plants, and electric and steam turbine filter supply pumps were provided in each 182 Building. A number of the electric pumps were removed after the modifications. Several were retained and are used on occasions when it is desired to pump water from the reservoir to the filter plant. The present number of electric filter supply pumps that can be operated in each 182 Building is shown below:

Pump Room	No. of Pumps	Capacity gal/min.	Head feet	Motor Horse Power
182-B	5	6000	100	200
182-D	5	6000	100	200
182-F	7	6000	100	200
182-H	9	6000	100	200

It is to be noted that the 182 Buildings still play an important part in the production reactor plant cooling system since they are the source of "export water" used for emergency cooling. Details of this function are covered in a later section of this report.

3. Filter Plant and Chemical Treatment - 183 Building

Although the Columbia River water is unusually clean and pure, it must be filtered and chemically treated to prevent filming in the reactor process tubes. This is the purpose of the 183 Building and its components.

There is a separate filter plant for each of the production reactor plants. The filter plant consists of a head house , raw water flume, mixing chambers, distribution flume, floculators, settling basins, collecting flume, influent flume, filters, effluent and backwash piping, effluent flumes, and clearwells. Figure III-2 illustrates the sequence of operations. The basins, filters, flumes, clearwells, and building framework are rein-

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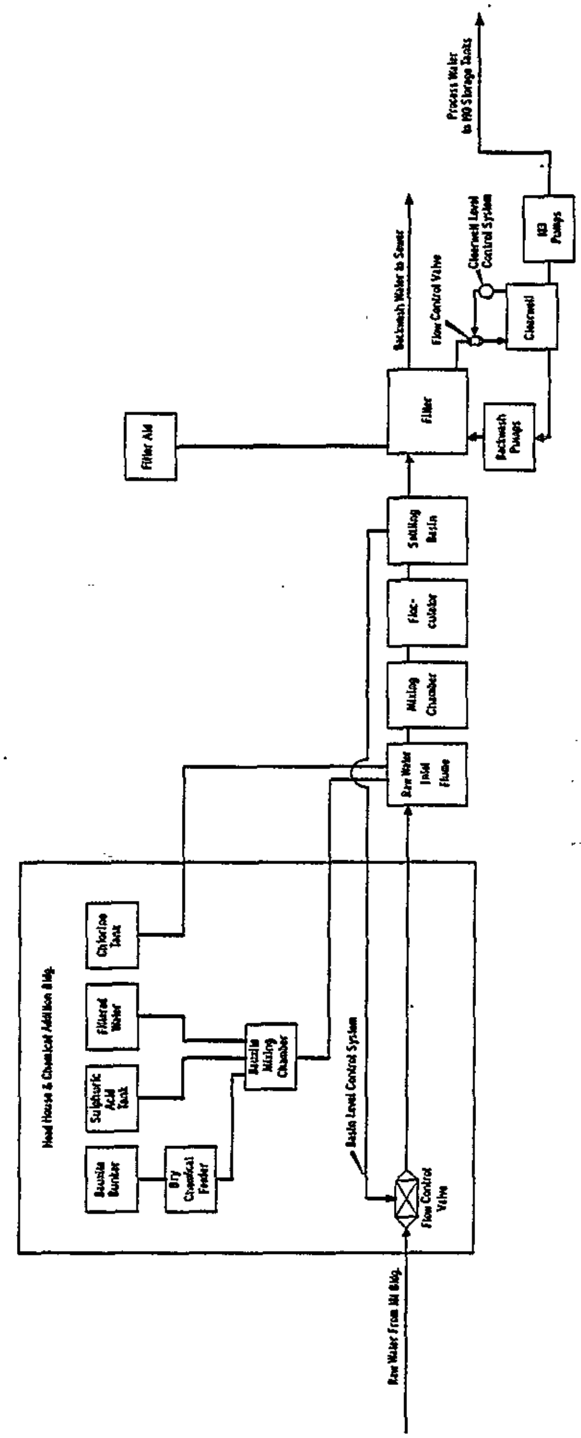

FIGURE III-2

Water Treatment Plant, 183 Building

forced concrete. The construction of the walls of the head house and filter buildings vary, being of either concrete block, or a steel frame covered with steel rib siding, or corrugated asbestos cement siding.

Each reactor is supplied with water from its own filter plant. However, the 183-C and the 183-D Buildings supply part of the water used by the B and DR Reactors, respectively. This is possible because of a cross-tie in the piping system.

a. Head House - 183 Building

River water enters the filter plants through two 36-inch carbon steel pipe lines. Water flow rate is regulated in the head house by a control valve in each of the two lines. These control valves are automatically operated and are positioned by a water level control system. The valves can also be manually operated by a switch located in the head house.

Alum, sulfuric acid, and chlorine are proportioned in the head house, and added to the raw water. The alum is used as a flocculating agent and the excess sulphuric acid is used to control the acidity of the water. Raw bauxite is stored in bunkers on the third floor of the head house and flows through a hopper to a proportional dry chemical feeder which supplies the bauxite at the required rate. From the conveyor belt of the proportional feeders, the bauxite falls into a lead-lined mixing chamber together with sulfuric acid and water. The reaction of the bauxite and diluted sulfuric acid forms a solution of alum and excess diluted sulfuric acid which is added to the raw water in the raw water flume. Chlorine is also added at this point for algae control in the settling basins.

Concentrated sulfuric acid is received in railroad cars and stored in outside acid storage tanks. It is pumped from the storage tank to a head tank through black iron pipe lines.

b. Mixing Chambers - 183 Buildings

There are one or more mixing chambers in each half of the filter plants. Water flows through the raw water flume into the distribution flume and into the mixing chambers. The purpose of these mixing chambers is to thoroughly mix the alum-sulfuric acid solution and chlorine with the raw water.

c. Flocculators and Settling Basins - 183 Building

The flocculators and settling basins are not enclosed for weather protection. There are two paddle-wheel flocculators in series for each settling basin in 183-B, D, and F and three in series at 183-C, DR, and H. The number of settling basins in each 183 Building is tabulated below. The purpose of the settling basins is to allow heavier particulate matter to settle out of the water before entering the filter.

Building	No. of Basins per Building	Capacity per Basin (gals)	Total Capacity per Building
183-B	12	4,800	57,600
183-C	8	18,700	149,600
183-D	16	4,800	76,800
183-DR	6	13,800	82,800
183-F	12	4,800	57,600
183-H	16	5,000	80,000

d. Filters - 183 Building

All filters are of the gravity flow type and are equipped with Wheeler bottoms. Each filter consists of two halves with a gullet between them. The 183-B, D, DR, and F filters have been rebuilt with new filter media consisting of approximately twelve inches of graded gravel, six inches of sand, and twenty four inches of crushed and graded anthracite coal. The 183-C and H filters still have an older type media consisting of about twelve inches of gravel, twenty inches of sand, and ten inches of crushed anthracite coal. Water enters the gullet from the influent flume through an influent valve and flows to both halves of the filter through port openings.

An organic polyelectrolyte filter aid is added to the water in the gullet to improve water quality by improving filter efficiency. The amount of filter aid material introduced varies with the condition of the raw water. The filtered water collects in the false bottom below the filter and flows through effluent piping to the effluent flumes. The amount of water passing through a filter may be automatically controlled by a valve in the effluent piping. This valve is operated by the clearwell water level control system. At the present operating flow rates, some of the control valves are locked open to provide the maximum volume of filtered water flow into the clearwells.

Water for filter backwashing is supplied from the clearwells by backwash pumps located in the pump room of the 183 Building. Backwash water enters the false bottom area, flows upward through the filter media into the gullet and out through a waste valve into a sewer. The 183-B, D, F, and H filter plants backwash cycle is manually controlled. The valves in the backwash sequence are hydraulically operated and are controlled from a panel located at each of the individual filters. The 183-C Filter Plant has a semi-automatic backwash cycle with a control panel for manual operation in the 183-C Pump Room. The filter backwash cycle for any one of the twelve 183-C filters can be started manually. The backwashing then automatically proceeds through its cycle to completion. The backwash water for the 183-DR filters is supplied from the 183-D Pump Room via a 30-inch carbon steel cross-tie pipe line to the 183-DR pipe gallery. This line is also used to supplement the 183-DR water requirements and is the 183-D-DR cross-tie line mentioned previously. An automatic backwash control system is currently being installed at 183-DR.

Building	No. of Filters	Size of Filters Sq. Ft.	Total Filtering Area - Sq. Ft.
183-B	12	1,152	13,824
183-C	12	2,304	27,648
183-D	16	1,152	18,432
183-DR	10	1,152	11,520
183-F	12	1,152	13,824
183-H	16	1,152	18,432

e. Clearwells - 183 Building

The clearwells, which are constructed of reinforced concrete, are covered by a flat slab concrete roof supported by concrete columns spaced approximately 20 feet apart. There are two separate clearwells in each filter plant separated by the pump room. At 183-B, D, F, and H, each clearwell has a suction well adjacent to the pump room. These two suction wells are connected to each other by a flume with a sluice gate at each end of the flume. The suction wells are connected to their respective clearwells by two sluice gates. Consequently, one suction well can obtain water from the other, and one clearwell can be drained while the other is full. At 183-C there is a common suction well between the two clearwells, valved so that one clearwell may be drained.

Each clearwell is supplied water from the filters through an effluent flume. The 183-F clearwells are different in design than those at 183-B, D, and H in that they cover a greater area, but are not as deep. The 183-C clearwells are considerably smaller than those at 183-B, D, F, and H.

This smaller clearwell storage at 183-C is compensated by larger storage tanks in the 190-C Building. There are no clearwells at the 183-DR Building. A 30-inch cross-tie line joins the 183-C clearwell to the 183-B clearwell. A lateral connection from this line is provided to one of the 36-inch water lines connecting the 183-B pump headers to the 190-B storage tanks. Water is transferred by gravity from the 183-C to the 183-B clearwells, and may be pumped from the 183-B to the 183-C clearwells.

The total storage capacity of the two clearwells in each of the five 183 filter plants is shown in tabular form below:

Building	Approximate Total Storage Capacity (gallons)
183-B	10,000,000
183-C	3,000,000
183-D	10,000,000
183-F	9,000,000
183-H	10,000,000

f. Pump Room - 183 Building

The 183 pump room is the primary supply point for filtered water for the entire production reactor plant and the associated limited area. For the primary reactor cooling system, pumps are provided to transfer water to the 190 storage tanks, to provide backwash water for the filters, and to provide water to the high tanks at the reactor. For other systems, as will be described in a subsequent section of this report, pumps are provided for power house water, fire and sanitary water, and for emergency filtered water.

The number and size of the electrically-driven water pumps in each 183 pump room for the primary reactor cooling system is shown in the table below:

Building	Number of Pumps	Capacity gal/min.	Head ft.	Motor hp	Use
183-B,F,H	6	15,000	150	700	Transfer to 190 tanks
	2	11,000	60	200	Backwash
	1	4,000	240	300	Hi tank & misc. cooling
183-C	5	21,000	55	450	Transfer to 190 tanks
	1	21,000	55	450	Backwash
	3	4,000	350	300	Hi tank & misc. cooling
183-D	6	15,000	150	700	Transfer to 190 tanks
	3	11,000	60	200	D & DR backwash & DR make-up
	1	6,000	240	450	Hi tank & misc. cooling

Note: Filtered water is transferred to the 190-DR storage tanks by gravity. Service requirements for 183-DR are supplied from 183-D.

i. Transfer Pumps - 183 Building

Filtered water is transferred from the clearwells to the 190 storage tanks by pumps, at the 183-B, C, D, F and H Buildings. Gravity flow is employed from 183-DR to 190-DR. At 183-B, 183-D, 183-F, and 183-H the pumps are located below ground level between the two suction wells. At 183-C, deepwell pumps are located above the suction well. There are six of the pumps, electrically driven, in each of these locations.

The suction piping for the 183-B, D, F, and H pumps is a 24-inch diameter pipe, with a gate valve, a rubber spool piece, and a cast iron inlet elbow. Three pumps are connected to each of the suction wells. Pumps are the horizontal, centrifugal type, driven by electric motors and set on concrete bases which are independent of the pump room floor. The 18-inch discharge piping contains a gate valve and a check valve and ties into 36-inch discharge headers, supported above the pumps. The headers for each of three pumps are connected together by a gate valve so that one-half of the header can be isolated from the other.

At 183-C, the pumps are of the deepwell type with submerged bowls and impellers. The 30-inch discharge pipes contain a gate valve and check valve and tie into two 48-inch headers. Three pumps discharge into each header. The headers supply filtered water to the 190-C storage tanks and backwash water for the 183-C filters.

ii. Backwash Pumps - 183 Building

At the 183-B, D, F, and H filter plants, separate backwash pumps are provided for backwashing the filters. There are two backwash pumps at 183-B, F, and H and three at 183-D. The three pumps at 183-D not only supply the backwash water for the 183-D and 183-DR filters, but also provide make-up water for the DR Reactor cooling water system.

The DR water plant system does not provide the entire primary coolant for the 105-DR Reactor, and make-up water must be obtained from 183-D. This make-up water is transferred from the 183-D Building to the north end of the 183-DR pipe gallery via a 30-inch tie line and then to the two 183-DR filter effluent flumes through a 24-inch pipe line. Flow is regulated by a butterfly valve manually controlled from the filter room in the 183-DR Building.

The valve arrangement in the 183-C Pump Room permits the use of any one of the six transfer pumps to be used for supplying the bakcwash water for the 183-C filters.

iii. 105 High-Tank Pumps - 183 Building

There is one electrically-driven pump in each of the 183-B, D, F and H Pump Rooms for supplying filtered water to the high-tanks at the respective 105 Buildings while three pumps are provided in the 183-C Pump Room.

Filtered water supplied by these pumps is also used for such purposes as cooling the primary coolant pumps and motors, filter controls and service, reactor thermal loop and control rod cooling.

iv. Pump Motor Electric Power - 183 Building

Transformer stations, located at the 183 Building, reduce the power line voltage of 13.8 kv to 2300 volts and supply two 2300 volt buses located in the switchgear room. All electric pumps are driven by three-phase, 2300 v, squirrel-cage, induction motors which are manually controlled. Bus ties are operated open, thereby preserving the dual power supply to each building with approximately one-half of the load on each bus.

g. Piping to 190 Storage Tanks

Cast iron, 36-inch, underground pipe lines transport the water from the discharge headers at the 183-B, D, F and H Buildings to the storage tank headers in the 190 Buildings. At 183-C two 48-inch lines are connected inside the building and form a common header for the 190 storage tanks.

The piping within the 183 pump rooms and within the 190 tank rooms is fabricated from rolled and welded carbon steel plate. The transition to cast-iron pipe occurs outside the respective buildings.

4. 190 Building and Pump Annex

a. Water Storage Tanks - 190 Building

Four large steel storage tanks are provided at each of the 190 buildings to supply water to the ~~coolant~~ pumps for the associated reactor. At 190-C and 190-DR the tanks are in the open, while those at 190-B, D, F, and H are enclosed in a cement block building. Water is supplied by 36-inch pipe lines which connect to opposite ends of a distribution header with sectionalizing valves inside of the 190 buildings. Each tank has its own inlet line, which enters at the bottom of the tank and contains a gate valve, a check valve, and a control valve. Normally, the control valves are automatically operated and are controlled by the storage tank water level. The control valves can also be manually adjusted to any position. Additional 14-inch inlet lines are presently being installed in the 190-B, D, and F Buildings to increase the flow capacity from the 183-Pumps and the 190-Tanks. A corrosion inhibitor, sodium dichromate, is added to the water at the tank inlet lines.

The tank discharge pipe lines tie into a common header, which supplies the two 42-inch lines to the 190-Annex Pump Room. There are also two 30-inch storage tank by-pass lines that are not normally used, which connect the storage tank inlet header to the storage tank outlet header.

A common header in the 183-C Building supplies water to the four 190-C tanks through four separate 30-inch pipe lines which enter the tanks at the bottom, but discharge near the top through a riser. Each tank inlet line contains a gate valve, a straightening vane, and a ball valve which automatically regulates flow to maintain a constant water level in the tanks. Each of the four tank discharge lines serve as a suction header for a portion of the high-lift pumps and each contains a motor operated gate valve. The four lines are also interconnected by motor operated gate valves.

The water flows, by gravity, from the 183-DR Building effluent flume directly to the 190-DR storage tanks through four 48-inch steel lines, one line for each tank, into the bottom of the tank. The tank discharge lines tie into a common header which forms two closed loops. Each of the loops is used as a suction header for four primary coolant pumps in the 190-DR Annex.

The capacity of the storage tanks, for all areas, is tabulated below:

Building	Storage Capacity at Each Tank	Total 190 Storage Capacity
190-B	1,750,000 gals.	7,000,000 gals.
190-D	1,750,000	7,000,000
190-F	1,750,000	7,000,000
190-C	5,250,000	21,000,000
190-DR	3,000,000	12,000,000
190-H	2,250,000	9,000,000

b. Primary Coolant Pumps - 190 Building Annex

i. 190-B, D, DR, F, and H Annex

The primary cooling water is pumped from the storage tanks and through the reactors by high-pressure pumps. The primary coolant pumps in the 100-B, D, F, and H Production Reactor Plants are housed in the 190 Annex Buildings which are constructed of a steel frame covered with corrugated asbestos cement siding. Each pump room at 190-B, D, F, and H contains eight electrically-driven, two-stage, horizontal centrifugal pumps. At 190-DR there are two pump rooms with four pumps in each. Each pump and drive assembly is supported on a concrete base which is entirely independent of the building. The pumps at 190-B, D, F, and H are identical. The 190-DR pumps have slightly different impellers because the available suction head is less.

The storage tanks provide a positive suction pressure, which is about 18 psig, for the 190-B, D, F, and H pumps and 8 psig for the 190-DR pumps. Normally, all eight pumps are used to supply the primary cooling water to an operating reactor. Water is drawn from the 42-inch diameter suction headers by the pumps through a 24-inch suction pipe which contains a gate valve and a rubber spool piece.

The pump and drive assembly is composed of a 4500 hp synchronous motor and a direct connected exciter, a 20-ton flywheel with a WR^2 of 500,640 lb/ft^2, a 1 to 2.618 speed increasing gear set, two flexible couplings, and a two-stage centrifugal pump. Figure III-3 illustrates this assembly. The flywheel speed is 720 revolutions per minute.

PRIMARY COOLANT PUMP AND DRIVE ASSEMBLY AT B, D, DR, F & H

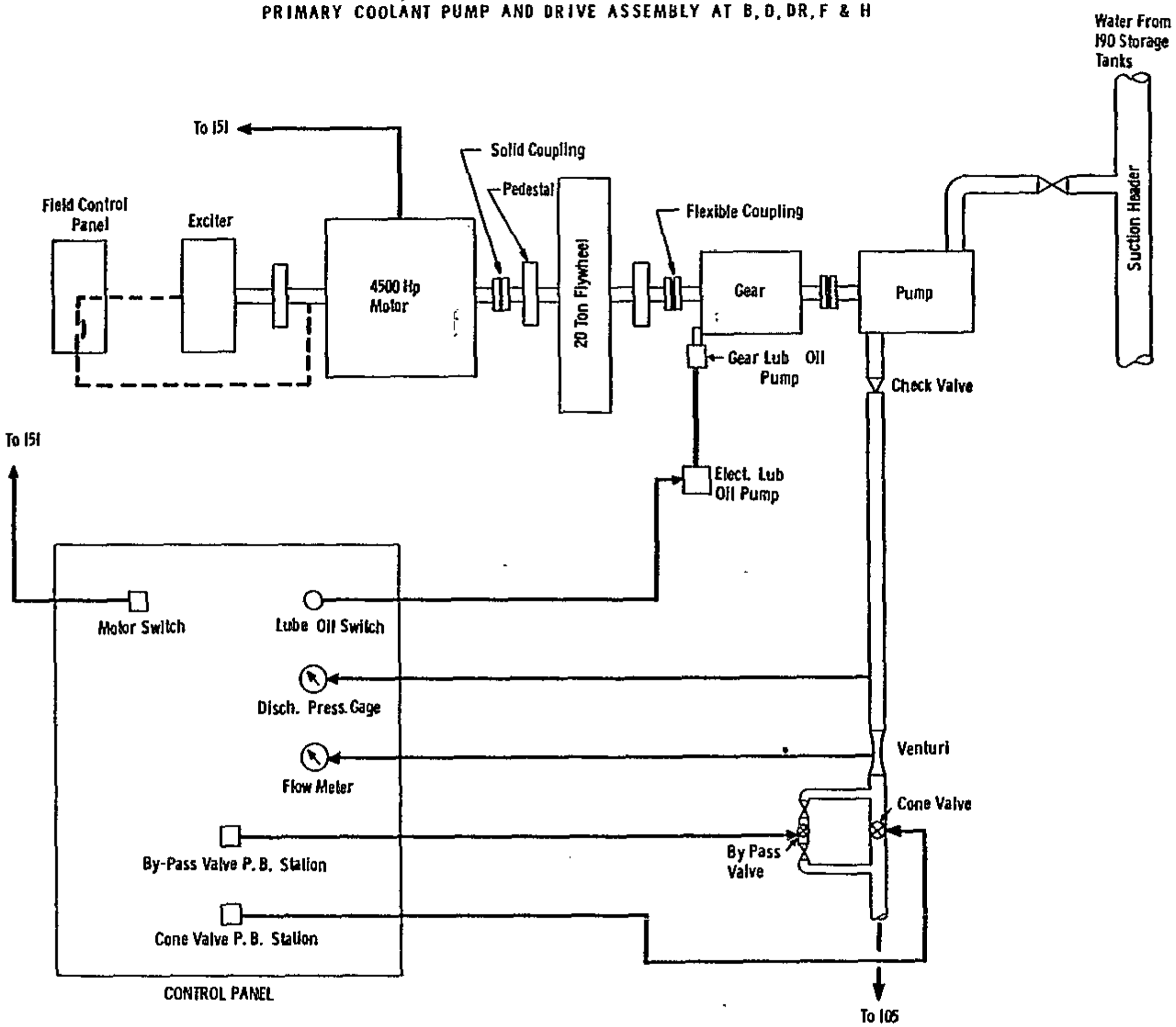

FIGURE III-3

Lubrication of the gears and bearings is accomplished by a pressure lubrication system which is supplied from an integral oil gear pump. It can also be provided by an electrically-driven auxiliary oil pump, powered by the emergency electrical bus in the pump room. This electrically-driven oil pump serves as a backup to the gear pump and supplies the lubrication during startup, and during the emergency shutdown period following the loss of primary electrical power. The lubrication oil is cooled, by water, in a heat-exchanger.

The pump discharge piping is 18-inch carbon steel pipe with a 3/4-inch thick wall. An 18-inch check valve, a venturi for flow measurement, and a 12-inch cone valve with a 6-inch by-pass line are components in the line. The by-pass line contains two 6-inch gate valves and a 6-inch globe valve for regulating water flow through the by-pass line. Both the 12-inch cone valve and the 6-inch globe valve have motor operators which are manually controlled from the pump control room. During normal operation, all cone valves are fully open and the reactor receives all the water the pumps can furnish.

The 190 Annex Building is joined to the 105 Reactor Building by two underground concrete pipe tunnels which contain the pump discharge piping. Each tunnel contains the discharge piping from four pumps. At B, D, and F, three of the four 18-inch discharge lines divide into two 12-inch lines. The remaining 18-inch line continues into the 105 Valve Pit where the seven discharge lines, each with a strainer, a check valve and a gate valve, tie into a 36-inch header. The two 36-inch valve pit headers are interconnected by motor-operated gate valves, which are normally closed. Figure III-4 illustrates the piping arrangement between the 190 Annex Building and the 105 Building valve pit for the B, D, and F Reactors.

At 190-DR, each of the 18-inch pump discharge lines divide into two 12-inch lines; four 12-inch lines then tie into one 24-inch line. The four 24-inch lines, two in each pipe tunnel, continue to the 105-DR valve pit. This is shown in Figure III-5.

Two 18-inch lines tie into a single 24-inch line in the 190-H Annex Building. The four 24-inch lines run to the 105-H valve pit through two separate pipe tunnels. This piping arrangement is shown in Figure III-6.

ii. 190-C

There are ten electrically-driven, high-pressure, primary cooling water pumps in the 190-C Pump Room, which is a steel frame building with transite siding. The pump and drive assemblies are supported on concrete bases, which are independent of the building foundations.

Water is supplied to the 190-C pumps by the 190-C Storage Tanks at a suction pressure of about 13 psig. The 24-inch pump suction lines from the storage tank headers contain a gate valve and a rubber spool piece.

The 190-C pump and drive assembly consists of a steam turbine, a 2.718 to 1 speed-reducer, a 3500 hp electric motor, a 1 to 1.425 speed-increaser, a fluid drive, a 9-ton flywheel with a WR^2 of 45,000 lb-ft^2, and single-stage pump assembled as shown in Figure III-7. Flywheel speed is 2460 rpm. Separate pressure-lubrication systems are provided for the turbine and gear, the motor, the speed-increaser, the fluid drive, the flywheel, and the pump. Each of the six systems is pressurized by a gear pump driven by the pump assembly drive shaft. The oil in each lubrication system is cooled by a heat-exchanger. There are no motor-driven auxiliary oil pumps, instead, a portable pressure pump is used to lubricate the flywheel bearings during startup.

The pump discharge is controlled by the pump speed, which is regulated by controls in the 190-C Pump Control Room. Normally, all ten of the pumps are used to supply primary cooling water to the operating reactor.

The piping configuration from the 190-C Pump Room to the 105-C Valve Pit is shown in Figure III-8. The number of primary coolant pumps in the 190 Buildings is tabulated below:

Primary Cooling Water Pumps

Building	No. of Pumps Each Building	Capacity gal/min	Head feet	Electric Motor Horsepower
190-B, D, F, DR, & H	8	10,400	1425	4500
190-C	10	10,700	1040	3500

iii. Pump Motor Electric Power

The 190 Annex primary cooling water pumps are driven by three-phase, 13.2 kv synchronous motors. The power supply cables are in underground conduits from the 151 Substations to the 190 Annex Buildings. The 190-C primary cooling water pumps are driven by three-phase, 4.16 kv squirrel cage induction motors. Transformers, one for each motor are located outside the 190-C Building to reduce the line voltage to 4.16 kv. All of the electric motors are controlled from the pump control room in the 190 Buildings.

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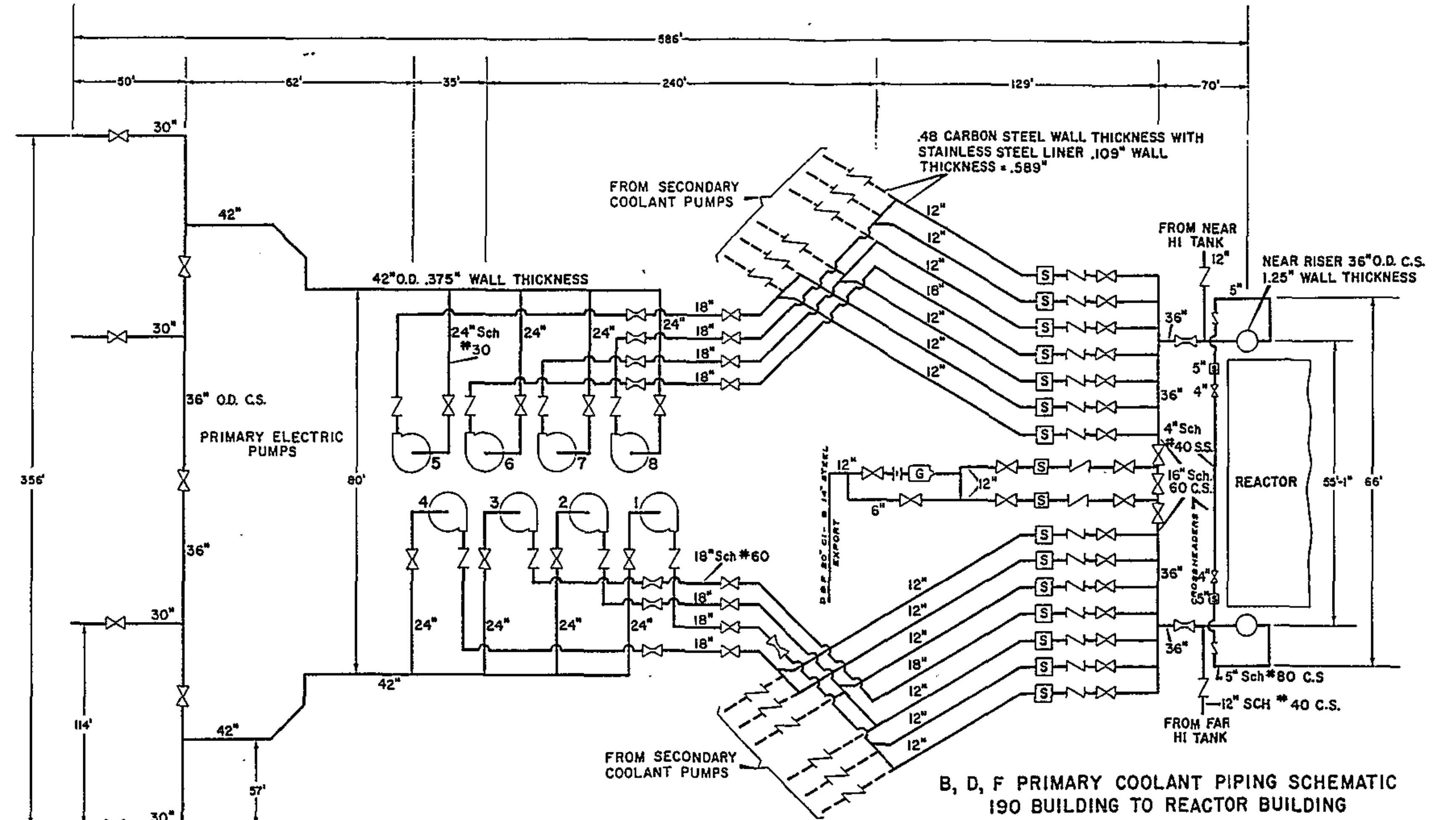

B, D, F PRIMARY COOLANT PIPING SCHEMATIC
190 BUILDING TO REACTOR BUILDING

Elevation Above Sea Level - FT.

	B	D	F
190 Bldg. Zero Level Floor Elevation	467.50'	467.00'	412.50'
105 Bldg. Zero Level Floor Elevation	468.50'	466.50'	413.25'
187 High Tank W. S. Elevation - No. 1	619.33'	621.83'	565.33'
187 High Tank W. S. Elevation - No. 2	627.33'	622.83'	569.33'

FIGURE III-4

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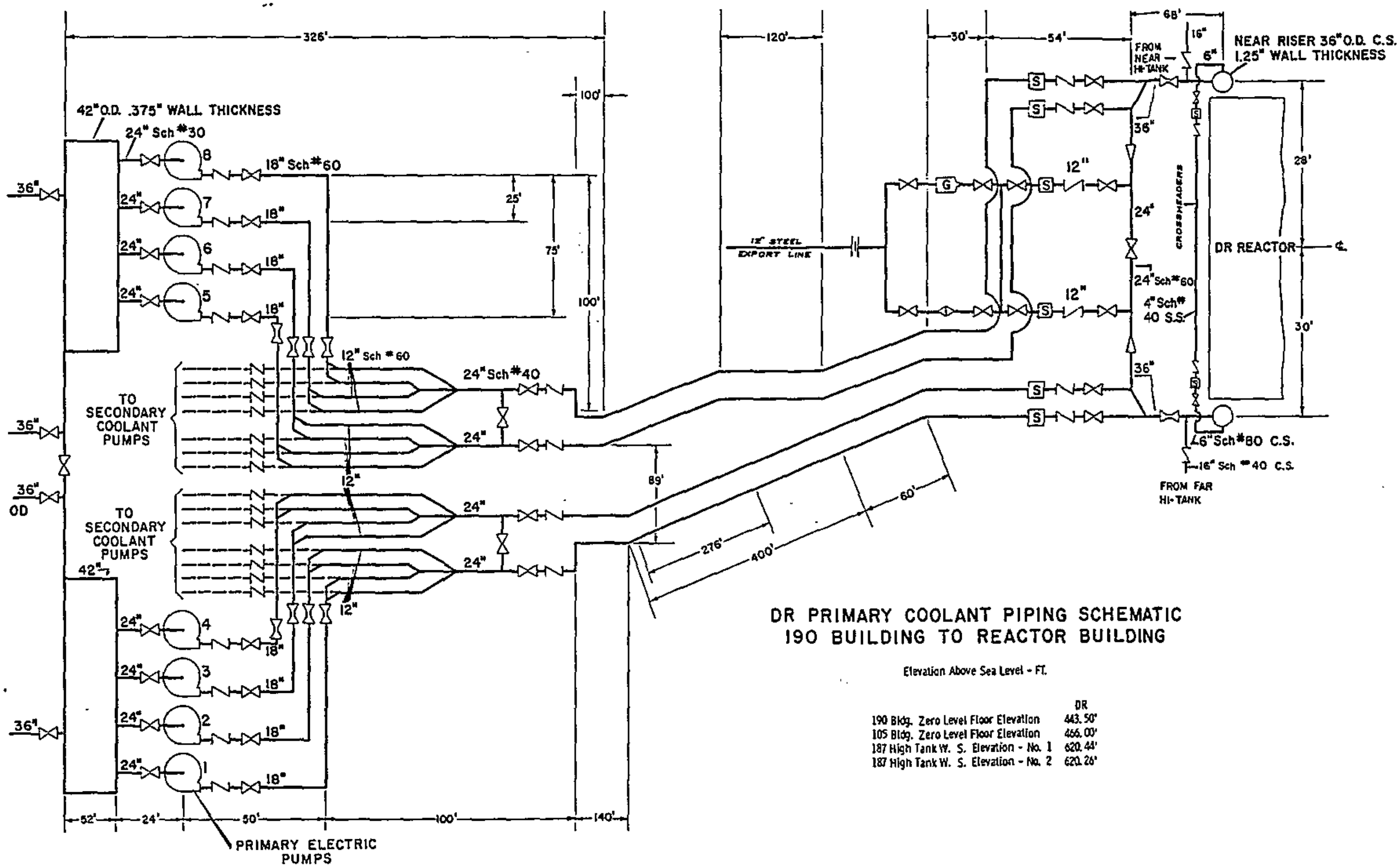

DR PRIMARY COOLANT PIPING SCHEMATIC
190 BUILDING TO REACTOR BUILDING

Elevation Above Sea Level - FT.

	DR
190 Bldg. Zero Level Floor Elevation	443.50'
105 Bldg. Zero Level Floor Elevation	466.00'
187 High Tank W. S. Elevation - No. 1	620.44'
187 High Tank W. S. Elevation - No. 2	620.26'

FIGURE III-5

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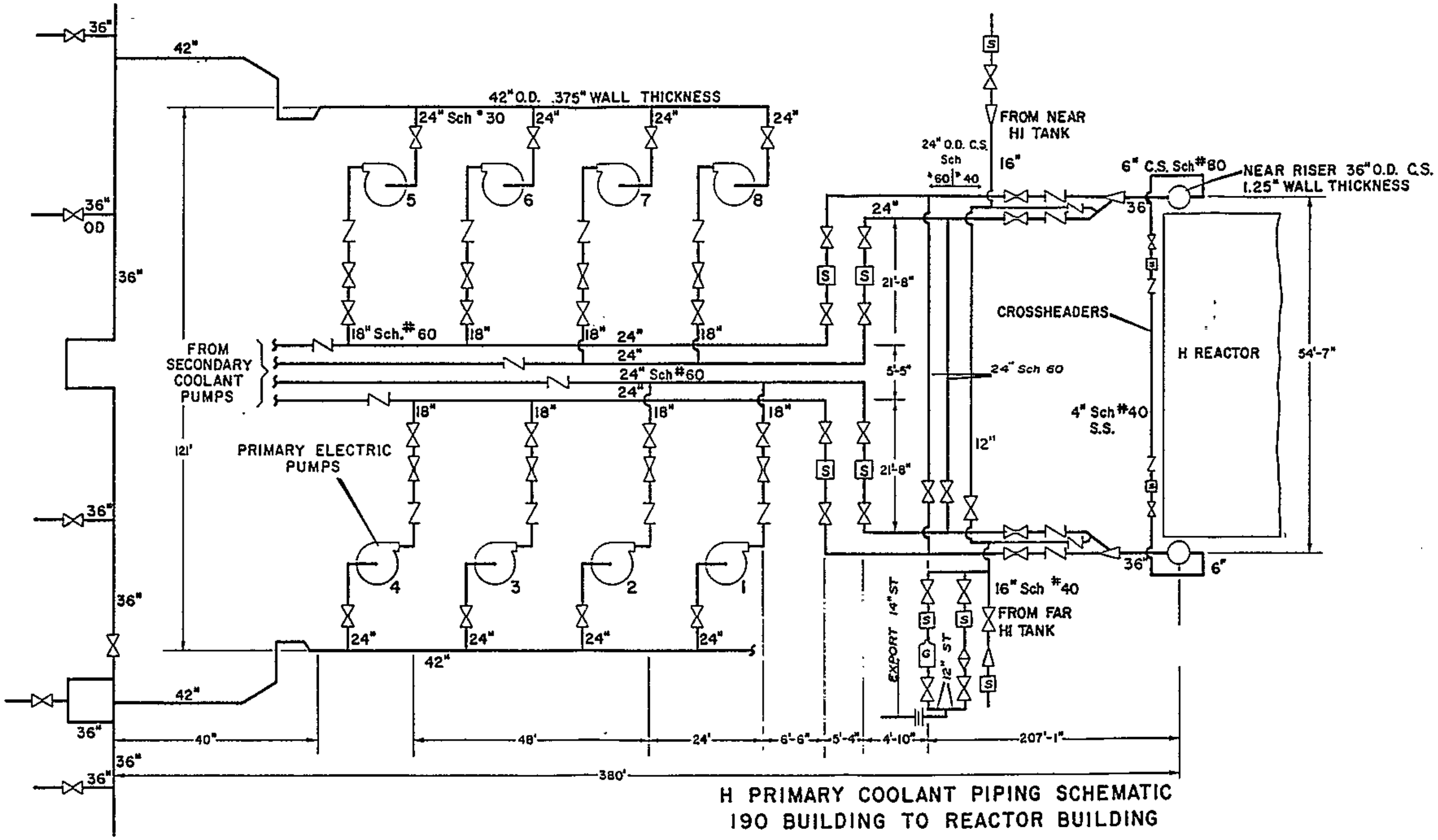

H PRIMARY COOLANT PIPING SCHEMATIC
190 BUILDING TO REACTOR BUILDING

Elevation Above Sea Level - FT.

	H
190 Bldg. Zero Level Floor Elevation	421.00'
105 Bldg. Zero Level Floor Elevation	423.00'
187 High Tank W. S. Elevation - No. 1	577.40'
187 High Tank W. S. Elevation - No. 2	577.44'

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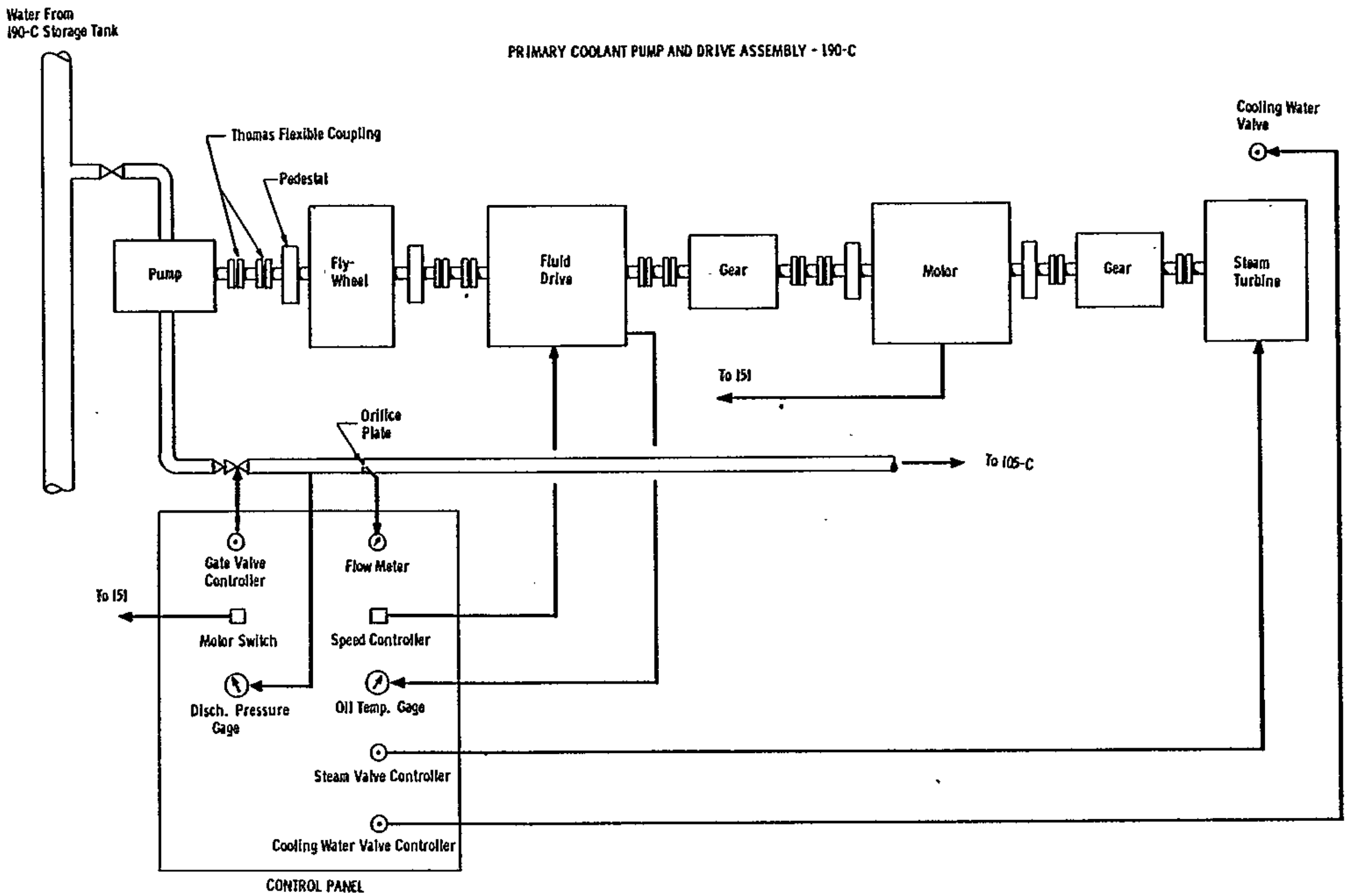

Water From
190-C Storage Tank
PRIMARY COOLANT PUMP AND DRIVE ASSEMBLY - 190-C
Thomas Flexible Coupling
Pedestal
Pump
Fly-Wheel
Fluid Drive
Gear
Motor
Gear
Steam Turbine
Cooling Water Valve
To 151
Orifice Plate
To 105-C
Gate Valve Controller
Flow Meter
To 151
Motor Switch
Speed Controller
Disch. Pressure Gage
Oil Temp. Gage
Steam Valve Controller
Cooling Water Valve Controller
CONTROL PANEL

FIGURE III-7

B. Secondary Coolant System

Total failure of the electric power to the Hanford site is considered a possibility. In such an event, a secondary power source is available. It is independent of the electrical, or primary source, and is capable of providing adequate cooling water to the reactor until the primary system can be re-established. It is not intended to duplicate the capabilities of the primary coolant system but should be regarded as a means of preventing damage to the reactor, which may result from overheating during the shutdown period following the loss of electrical power.

A steam plant is provided at each reactor plant which can supply power to turbines for driving the secondary cooling water pumps. These boilers are kept on a stand-by basis, and are capable of rapid response.

1. Power House - 184 Building

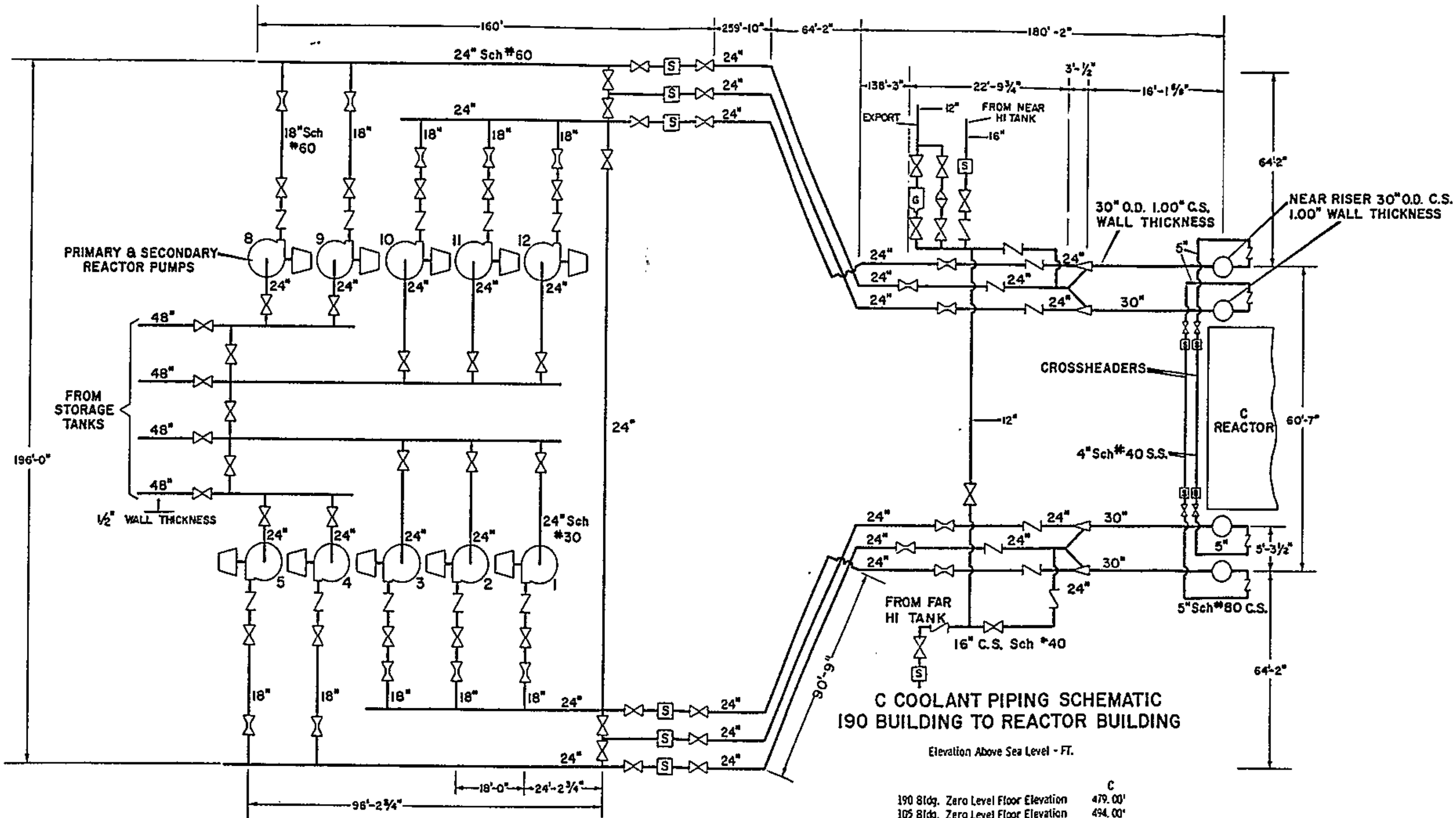
Each of the 184-B, F, and H Buildings contain four boilers, while the 184-D contains five. These boilers are all identical and are coal-fired, two drum-type with superheater. Each boiler has a rated capacity of 100,000 pounds steam per hour at 225 psig and 460 degrees F. and can produce 135,000 pounds of steam for short periods of time.

At the 184-B, D, and F Buildings, a 290 ton capacity coal bunker (230 tons at 184-H) is provided for each boiler. In each building, an electric drum-flight conveyor across the bottom of all coal bunkers provides a means of transferring coal from any bunker to any boiler. Coal is delivered by gravity from the bunker to the stoker-feeder hopper serving five steam turbine-driven stokers at each boiler. Coal is transferred from railroad cars to the bunkers or the coal storage pile by an electric-driven belt conveyor system having a capacity of 150 tons per hour. The coal supply system is illustrated in Figure III-9.

A steam turbine-driven, forced-draft fan of 45,000 cubic feet per minute (cfm) capacity is provided for each boiler. These fans discharge into a sectionalized duct that delivers air from any fan to any boiler. The furnace gas is discharged into 300-foot high stacks. The 184-B, F and H Building have two stacks each, and the 184-D has three.

Boiler feedwater is provided from four sources of supply, the first three being filtered water from the 183 Building and the fourth, a last ditch source, is raw water from the reservoirs at the 182 Building.

The first feedwater source, for normal operation, is supplied by two 1000 gpm pumps. One is steam and the other electrically driven.



C COOLANT PIPING SCHEMATIC
190 BUILDING TO REACTOR BUILDING

Elevation Above Sea Level - FT.

	C
190 Bldg. Zero Level Floor Elevation	479.00'
105 Bldg. Zero Level Floor Elevation	494.00'
187 High Tank W. S. Elevation - No. 1	663.00'
187 High Tank W. S. Elevation - No. 2	663.00'

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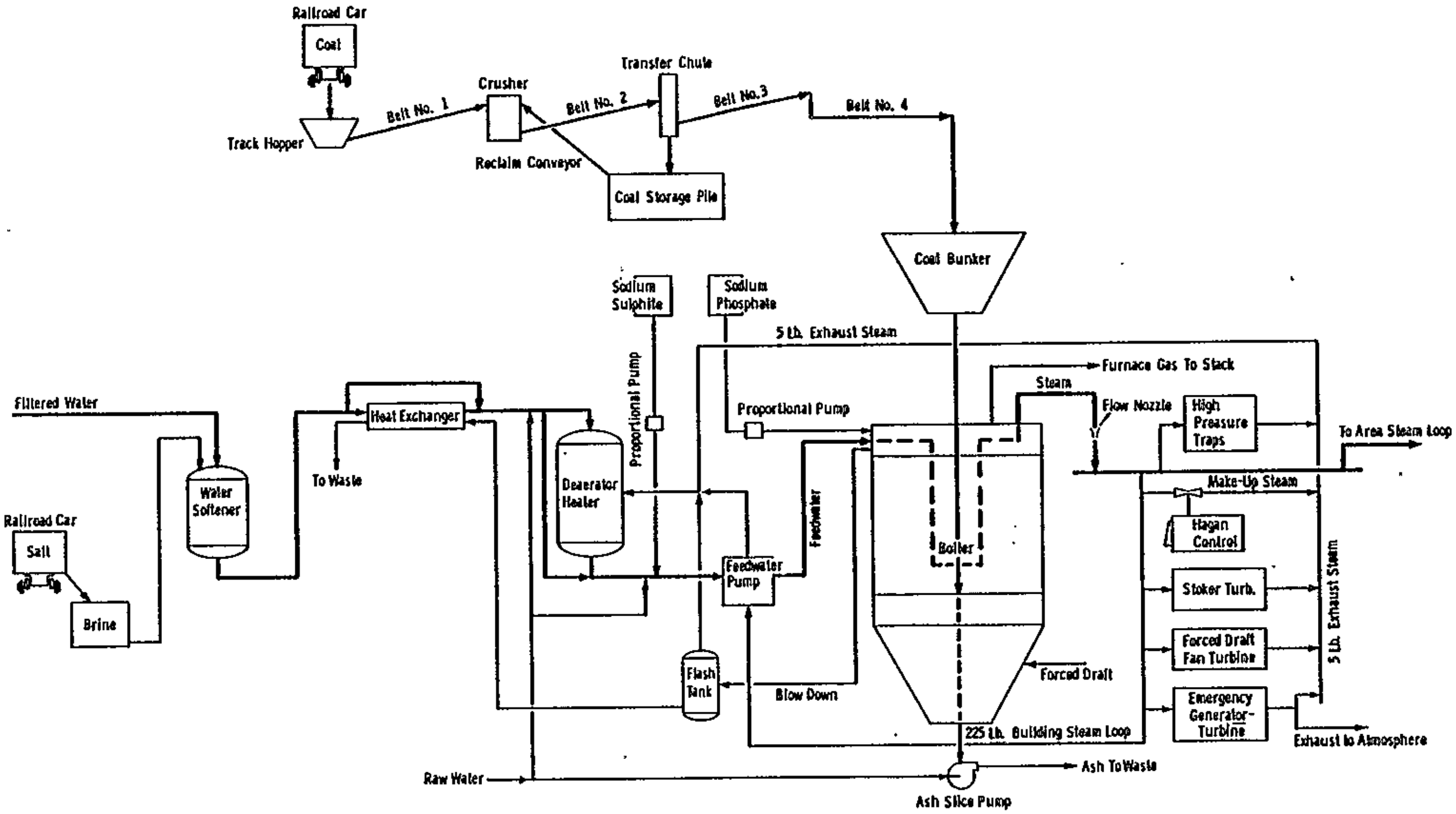

FIGURE III-9

Flow Diagram of a Typical 184 Building Power House

The second, or emergency feedwater source is supplied by four 4000 gpm pumps; three are steam turbine-driven and one electric motor-driven. These pumps discharge into a common manifold, which is separated from the normal supply line by a manually-operated valve.

The third feedwater source is a 100,000 gallon high-tank, filled from the fire and sanitary water system. Feedwater is automatically supplied from the tank upon loss of pressure in the first feedwater supply.

The fourth, or last ditch, feedwater source is the condenser water system which can be connected to either the deaerator or boiler feedwater pump suction header through manually-operated valves.

Three Zeolite (Zeo Dur) water softeners in each power house are interconnected by inlet and outlet manifolds. Only filtered water is softened, and normally flows from the softener through the heat exchanger. A by-pass permits this water to be diverted directly to either the deaerator heater or feedwater pump suction header.

There are four steam turbine-driven, two-stage, feedwater pumps in each power house, each having a capacity of 200 gpm at 300 psig. The turbines are equipped with differential pressure regulating governors and an overspeed trip. The pumps discharge into twin loop headers, permitting water to be delivered to any boiler at either end of the upper drum. At one end of the drum a two element flow regulator maintains proper water level in the drum, while at the other end water is admitted through a manually-operated valve. The flow regulator is preceded by a flow metering orifice.

Electrical power is furnished from the 151 Substation through a 13.8 kv feeder line and transformed to 2300 v, 440 v and 110 v at the Power House Substation. The 2300 v feeders are connected to the emergency bus located on the second floor of the 184 Building and to the normal service bus located on the first floor. The 440/220/110 voltages are fed to appropriate distribution panels.

In the event of interruption of the normal electric power supply, a 60-cell storage battery provides essential light for the building and supplies direct current for switchgear operation until the emergency turbo-generator begins to supply emergency electrical power. All of the electrical facilities in the power house can be supplied with power by this turbo-generator.

The rate of firing the boiler is regulated by an automatic control system with optional manual controls. Compressed air for this system is furnished by a two-stage, electric-driven compressor. A locomotive-type, steam-driven compressor is provided for emergency back-up. Two 150 cubic feet air receivers maintain a reserve supply of compressed air. The control air is filtered and delivered to the components of the firing control system through a pipe loop to all the boilers.

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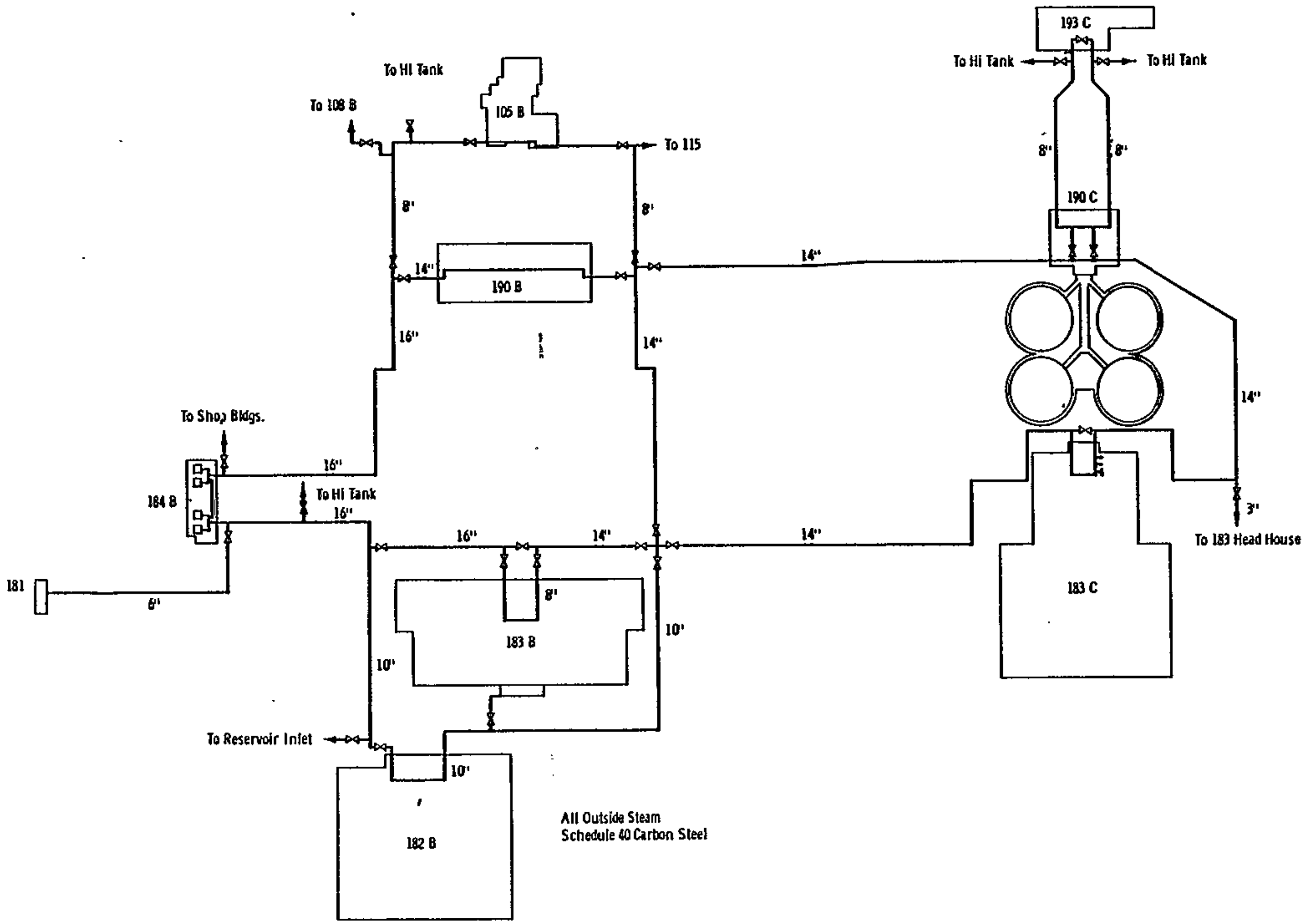

FIGURE III-10

Steam Distribution System, 100-B Area

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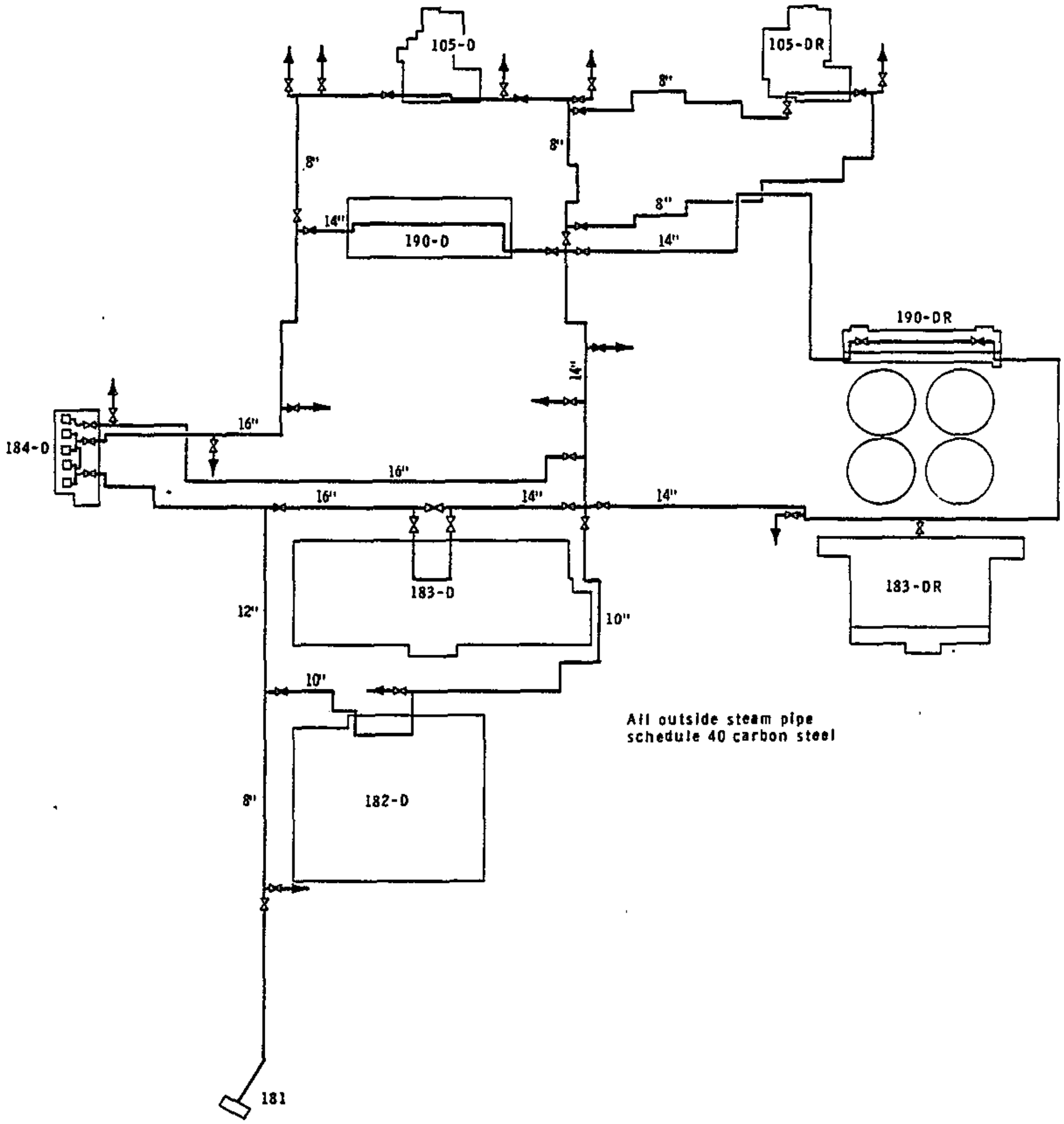

FIGURE III-11

Steam Distribution System, 100-D Area

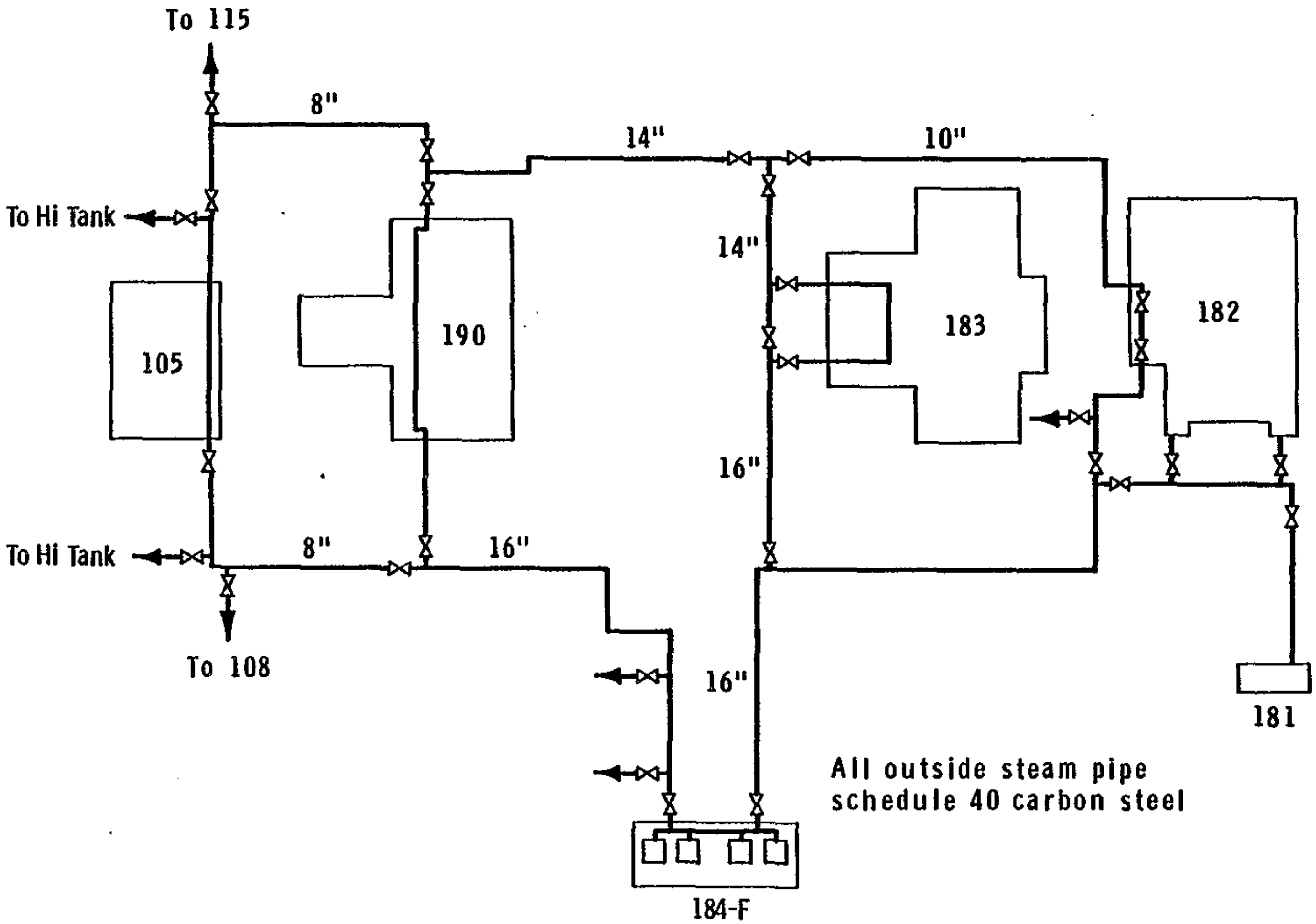

FIGURE III-12

Steam Distribution System, 100-F Area

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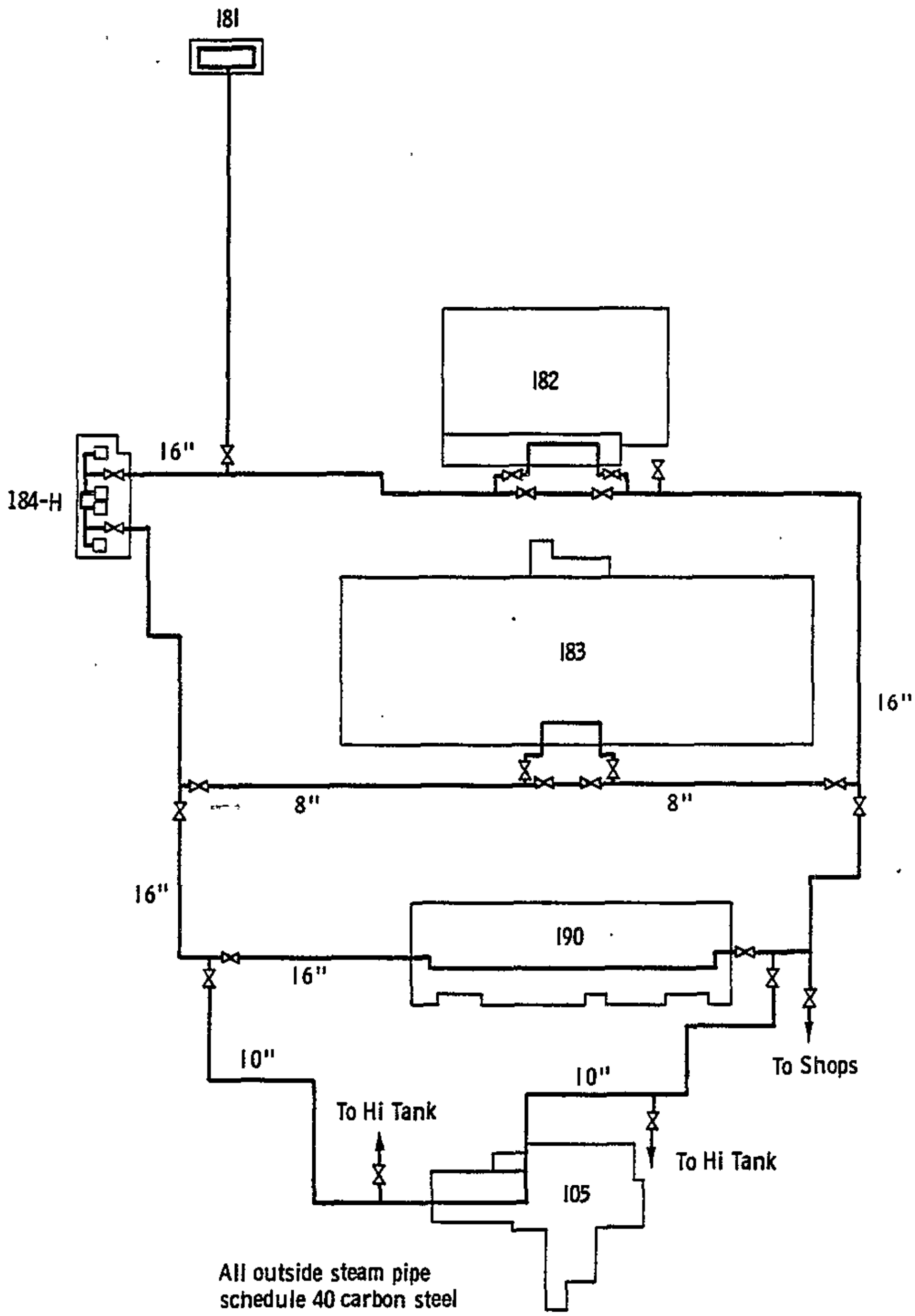

FIGURE III-13

Steam Distribution System, 100-H Area

Furnace ash is removed by dumping it into a pit beneath the furnace. This ash and the fly ash is sluiced into a trench running through the building and emptying into a sump. The wet ash is then pumped from the sump into an ash pit.

Steam flow within the power house is illustrated in Figure III-9. Export steam flow in the various areas to the buildings outside of the power house is illustrated in Figures III-10, III-11, III-12 and III-13.

Boiler water treatment chemicals, sodium sulfite and tri-sodium phosphate, are delivered to the power house in bags and stored in the chemical mixing room. Sodium chloride salt is delivered in carload lots and unloaded into brine pits.

A modification of one boiler in the 184-H Area will be used to test auxiliary oil burning equipment.

2. River Pump House - 181 Building

The secondary coolant system components at the river pump house are steam turbine-driven, vertical pumps. A right-angle gear acts as a speed reducer between the turbine and the pump providing a gear ratio of 3 to 1, reducing the turbine speed of 2640 rpm to a pump speed of 880 rpm. The number, and capacity, of the steam turbine pumps in each of the 181 Buildings is tabulated in the description of the 181 Buildings, but is repeated below for convenient reference.

Pump House	Number of Pumps	Capacity (gal. per min.)	Head (feet)	Turbine Rating (hp)
181-B	2	7500	150	400
181-C	None			
181-D	2	7500	150	400
181-DR	None			
181-F	3	7500	150	400
181-H	3	7500	150	400

The steam turbines do not start automatically upon loss of power to the electric pumps, but must be manually started by opening the steam valves at the turbines. The speed of the turbines and pumps is regulated and controlled by a mechanical-type governor with an excepted regulation of eight percent or better.

The discharge piping of the turbine-driven river-water pumps connects to a header which supplies water to the 30-inch line to the reservoirs at the 182 Building. A cross-tie line between the reservoir water line and one of the primary coolant water lines between the 181 and the 183 Buildings makes it possible for the pumps to supply water to either the reservoirs or the filter plant.

3. Reservoir and Pump House - 182 Building

Water for the secondary coolant system can be drawn from the reservoirs of the 182 Building if the river water secondary pumps are unable to pump water to the filter plant at the 183 Building. The capacity of the reservoirs is tabulated below.

Reactor Area	Reservoir Capacity (182 Building) (gals.)
100-B	25,000,000
100-D	25,000,000
100-F	25,000,000
100-H	10,000,000

There are three steam turbine-driven filter supply pumps in the 182-B and 182-F Pump Rooms and four in the 182-D and 182-H Pump Rooms. The pumps are 4000 gpm capacity, 250-foot head discharge pressure, 350 hp units. They are direct-drive units and the turbines have a mechanical-type governor, with an expected regulation of eight percent or better.

All steam turbines supplying water from the 182 Buildings to the filter plants must be started manually by opening the turbine steam valve. A turbine governor controls the speed of the pumps once they are in operation.

The 12-inch pump discharge piping contains a gate valve and check valve, and ties into the filter supply header. This header is connected in turn to each of the two primary coolant lines that run from the river pump house to the filter plant. A 24-inch pipe line runs from the filter supply header at the 182-B and 182-D Buildings to the inlet piping at the 183-C and 183-DR Buildings, respectively. This cross-tie line provides a source of secondary coolant water to the 183-C and 183-DR filter plants. Consequently, all six of the old filter plants can be supplied secondary coolant water from the four reservoirs at the respective 182 Building.

4. Filter Plant - 183 Building

At each of the filter plant pump rooms, there are three steam turbine-driven pumps. At 183-B, D, F, and H they are rated at 4000 gpm, 250-foot head, and are direct-drive 350 hp units. At 183-C they are rated as 4000 gpm, 350-foot head, 325 hp units and have a 2.25 to 1 gear speed-reducer. These units can be used to supply water to the 190 Building storage tanks in the event of loss of power to the transfer pumps in the 183 Building.

At 183-B, D, F, and H there is a 24-inch connection between the filtered service water line and one of the primary coolant lines which interconnect the 183 and 190 Buildings. At 183-C the tie between the filtered service water line and the primary coolant line is inside the 183-C Building. These tie-lines are normally closed by a motor-operated gate valve and must be opened before the turbine pumps can supply water to the 105 Building high-tanks.

At least one of the three steam turbine pumps has an automatic control which will start the steam turbine in the event of power failure to the electrically driven pumps. The remaining units must be started manually. The speed of the turbines is controlled by a mechanical-type governor, with an expected regulation of eight percent or better.

To provide water to the power house boilers during an electric outage, each of the 183-B, D, F, and H Pump Rooms contains one 1000 gpm, 165-foot head, 50 hp turbine-driven boiler water pump as well as the normal electric pump of the same size. This pump has a direct drive and must be started manually. The speed is controlled by a governor.

5. Secondary Coolant Pumps - 190 Building

a. 190-B, D, DR, F and H

The most important link in the secondary coolant system is the steam turbine pumps in the 190 Building. These pumps provide backup for the primary coolant pumps in the 190 Annex in the event of an electric power failure. These pumps are also used as an operating convenience to supply cooling water to the reactor during a normal reactor outage. Each of the five 190 Buildings contain from 12 to 16 steam turbine pumps that can be used as a secondary water supply to the reactor.

At the 190-B, D, and F Buildings, the turbines are direct drive. In the 190-DR and H Buildings, there is a gear speed-reducer (1.82 to 1 ratio at DR and 1.79 to 1 ratio at H) between the turbine and pump. The steam is supplied to the turbine through a 6-inch pipe line from a header in the pump room.

Each turbine is equipped with a condenser but can be operated either as a condensing or non-condensing unit. The turbine regulation of eight percent or better is accomplished by a mechanical governor which is set to maintain the desired speed of the turbine from zero to full load. A speed indicator is mounted on all turbines. The supply line to each turbine contains a steam control valve which may override the governor valve on the shaft and slow down the speed of the turbine by reducing the steam supply to the turbine. The steam control valves are operated by air pressure and controlled by speed regulators.

The suction piping of the turbine-driven pumps is tied to the same 190 storage tank header that supplies the primary pumps. The discharge piping ties into the primary coolant piping downstream from the 190 Annex pumps. At 190-B, D, and F, the twelve secondary coolant discharge lines tie into the twelve 12-inch primary coolant lines in the pipe tunnels at the end of the Annex Building. At 190-DR, the fourteen secondary lines tie into fourteen of the sixteen 12-inch primary coolant lines in the 190-DR tunnels. At 190-H, the sixteen secondary lines tie into four 24-inch headers in the 190-H Building. The four 24-inch headers then tie into the four 24-inch primary coolant lines in the 190-H Annex Building. A typical coolant system arrangement is shown in Figure III-14.

The number and size of turbines and pumps in each of the 190-B, D, F, DR, and H Buildings is shown below:

Building	No. of Pumps	Capacity (gal/min)	Head (feet)	Turbine (hp)
190-B	12	3000	352	575
190-D	12	3000	352	575
190-DR	14	3000	352	575
190-F	12	3000	352	575
190-H	16	3000	352	575

Note: In 190-C the secondary system consists of a steam turbine connected to the same drive train used for the primary pumps, i.e., an alternate power source is used rather than an alternate pump.

In each of the 190 Buildings electrically-driven and steam-driven air compressors are provided to supply air for instruments and controls. The steam-driven units act as backup for the electrical compressors and can supply

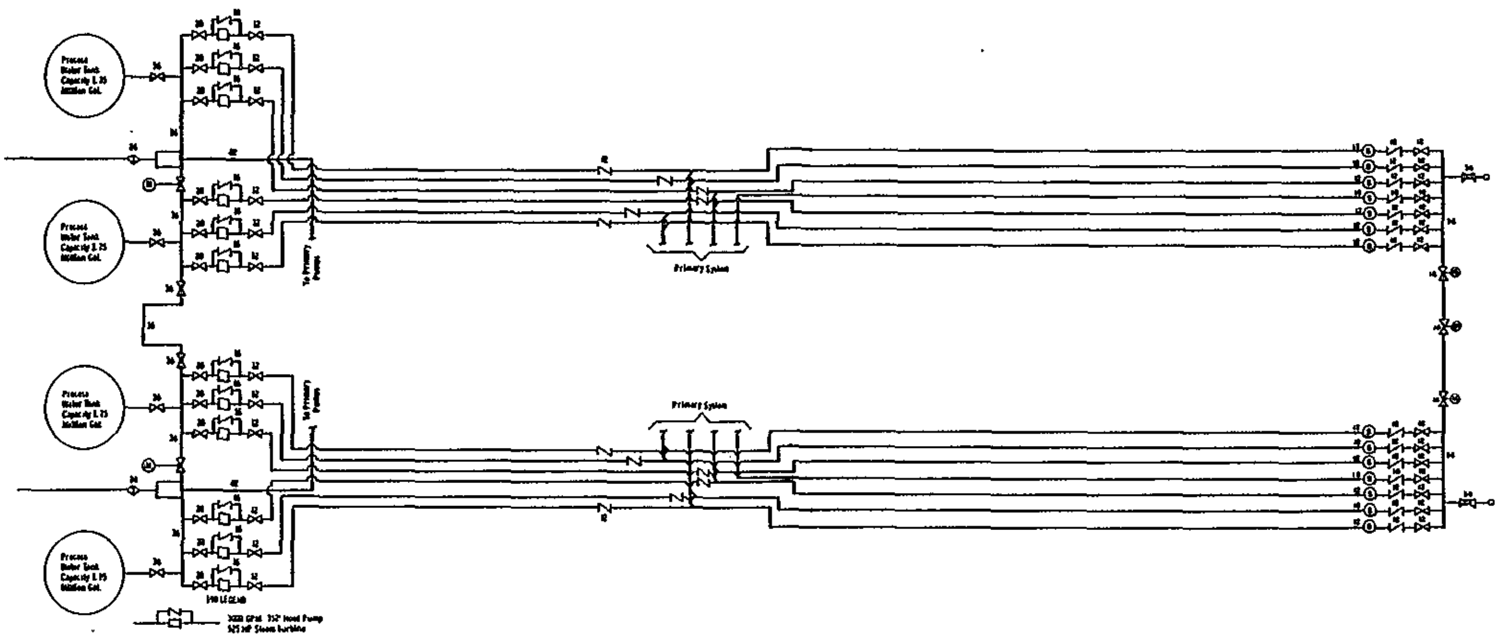

FIGURE III-14

B, D, and F Secondary Coolant Piping, 190 Building to Reactor Building the air for the 190 tank inlet control valves and the steam control valves on the 190 turbine pumps. Air pressure is automatically controlled by governor in the steam supply to each compressor. A lubricator is installed on the steam line to each compressor to lubricate the steam cylinders.

The instrumentation for each of the 190-B, D, DR, F, and H secondary pumping units consists of a steam turbine exhaust pressure gage, a pump discharge pressure gage, a pump suction pressure gage, a flowmeter, an individual pump speed controller, and a manual-automatic switch for the speed controllers. These gages are mounted on control panels in the 190 Building Pump Rooms. Each panel contains the gages and controls for three pumps along with an air pressure gage and one riser pressure gage.

The speed controller regulates the speed of the turbine by opening and closing the steam control valve. When the speed controller switch for a unit is set on "manual", the steam control valve for that unit is regulated by the speed controller on the control panel board. When the speed controller switch is set on automatic the pump speed can be controlled by the master speed controller in the 190 Control Room.

Under normal operation, seven steam turbines in each of the 190-B, D, DR, F, and H Buildings have the speed controllers set on automatic and are operating at about 300 to 500 rpm with the steam supplied through a 3/4-inch bypass line. In the event that one of the electric pumps trips off, or the top of riser pressure (TORP) in the reactor inlet riser drops about 130 psi, the steam control valves of all seven turbines open and the turbines accelerate to governor speed in about 45 seconds. These seven turbines operating at the present governor speed of about 1900 rpm will produce a top of riser pressure in excess of 75 psi. The master controller can then reduce the pump speed, and consequently the reactor flow as determined by the flow requirements.

b. 190-C Building

At the 190-C Building, the secondary coolant system steam turbine is a part of the primary coolant pump drive set, as shown on Figure III-7. The steam turbine is coupled to the pump drive shaft and turns continuously when the electric motor is running. During the normal pumping operation, the turbine is driven by the electric motor and does not contribute to the driving of the pump. The turbine governor is set to open the steam supply valve at a lower turbine speed than that produced by the electric motor, and to shut off the steam supply to the turbine when the electric motors are running. A bypass is provided to supply a small amount of steam for cooling the turbine during normal operation.

In the event of an electric power failure, the steam turbine will take over and drive the pump as soon as the turbine speed reaches the governor range. The speed of the turbines can then be reduced, from the 190-C Control Room, by adjusting the steam valve controller. All ten pumps would continue to run and be driven by the steam turbines if all electric motors were lost. When all ten turbines are running, each pump will supply about 3900 gpm, giving a total flow to the reactor of 39000 gpm.

C. Last Ditch System

The last ditch cooling system is designed to provide adequate cooling water to meet reactor shutdown requirements indefinitely. This has been done by providing two major components in the system; the reactor high tanks and the export water pipe line.

1. High Tanks - 105 Building

Each reactor has two 300,000 gallon high tanks which, by the use of check valves, automatically supply water whenever the line pressure to the reactor falls below the static head pressure of the tanks. The flow is adequate to satisfy the cooling requirements of the reactor for the period between the decreasing water flow from the primary coolant pumps, which are coasting down on flywheel inertia, and the continuous low flow from the export water system.

a. 105-B, D, and F High Tanks

These tanks are steel, free standing structures, with a total height of about 160 feet and a water level about 154 feet above the zero level of the reactor and about 117 feet above the top of the inlet riser. The tank is cylindrical, with elliptical heads top and bottom, and is connected to a 60-inch diameter riser with a 1/4-inch wall thickness. The tank is constructed with a 13/32-inch thick plate bottom head, 3/8-inch thick lower side plates, and 1/4-inch thick for the remaining side plates and top head. The riser is stayed at bracing levels by radial spider rods attached to each of the six legs. Horizontal struts at each of five bracing levels consist of pairs of channels, one flat and the other vertical, varying in depth from seven to ten inches.

The tank drain lines are 12-inch diameter, schedule 30 carbon steel pipe. Water enters the drain lines at a point five feet from the bottom of the riser and passes through a gate valve, normally opened, to a dual strainer. To increase the tank draining rate, the gates have been removed from the strainers and both strainers are used in parallel.

b. 105-DR and H High Tanks

These tanks are similar to those at 105-B, D, and F except that they are approximately 154-feet high with a water level 151-feet above the zero-foot level of the reactor and about 114-feet above the top of the inlet riser. Three bracing levels are used rather than the five for the older tanks. The tank discharge piping is 16-inch diameter, Schedule 30 carbon steel pipe. At 105-H, a 12-inch carbon steel line interconnects the two high tank discharge lines upstream of the check valves. This line was installed so that export water could be provided to both reactor inlet risers.

c. 105-C High Tanks

These tanks are similar to the others except that they are higher, approximately 175 feet to the top, with a water level approximately 167 feet above the zero foot level of the reactor and about 132 feet above the top of the inlet riser. Diagonal bracing consists of flat bars which vary in size from five inches by one inch thick to six inches by one and three-eighths inches thick. The tank discharge piping is 16-inches in diameter. These discharge lines are also provided with a 12-inch pipe which interconnects both high tank discharge lines upstream of the check valves to provide water from the export pipe line to both reactor inlet risers.

2. Export Water System

The export water system serves the dual function of supplying emergency raw water to the reactors and also supplying the entire raw water requirements of the chemical processing areas. When used for the reactor emergency function, the system is considered to be a source of raw water for the reactor, or reactors, which have experienced a total loss of electrical and steam power. The various equipment settings and operating sequences outlined herein are subject to change as the results of current testing programs are evaluated.

a. Pipe and Pumping Facilities

Raw water is supplied to the export system by pumps in the 182 Reservoir Building in each reactor area. The principal system piping is presented in Figure III-15 which shows the important connections and the lengths and diameters of the various branches. The lines shown in this figure are concrete cylinder pipe, which consists of a 12/64-inch thick steel shell lined with 1/2-inch thick (nominal) centrifugally-cast cement mortar, reinforced with spirally-wound steel rod, spaced on approximately two-inch centers.

The outside shell of the pipe is covered with concrete, and the joints between the 30-foot sections are bell and spigot type with rubber gaskets. The pipe is buried to a depth of approximately 3 feet and is provided with appropriate air vents, drains and anchors. Typical 182 Building pumping systems and 105 Building valve-pit connections of the export system are shown in Figure III-16.

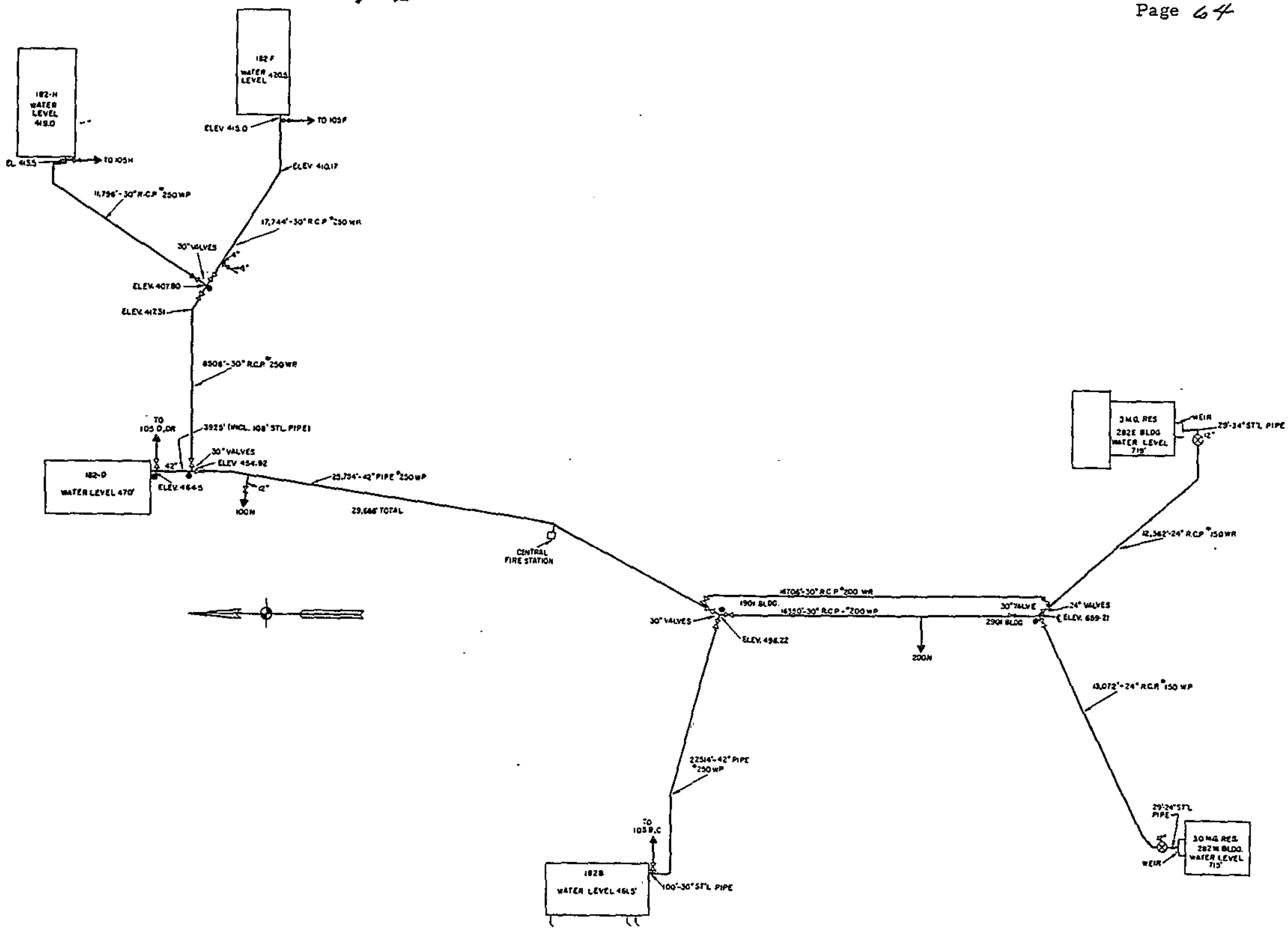

FIGURE III-15

Export Water Piping System

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Each of the 182-B, D, F and H Buildings has two raw water reservoirs of 15 million and 10 million gallon capacity, respectively. The 182-H Building reservoirs have capacities of 4 and 6 million gallons. These reservoirs are physically separated from one another by a dividing wall and both are supplied by the river pumps, either electric or steam. The export water pumps draw from compartmented suction wells connected to the smaller of the two sections.

All of the electric motor-driven export pumps are provided with solenoid-operated cone-check valves which are set to close automatically upon failure of the electric power.

These valves are actuated by oil pressure and timed to an emergency closure rate which is a compromise between protection against high-speed reverse pump rotation and water-hammer effects of too-rapid closure. The time of closing is set at a maximum of 10 seconds.

The cone check valve on the steam-driven export pump is actuated by water pressure from the export header, and can be set to automatically control the discharge from the pump to match the flow demands of the system. The controls of this valve are independent of electrical power.

All export pumps discharge into a common header, as shown in Figure III-16. This header is connected to the export water system at one end and, through a manually-operated cone valve, can be used to import water from other reactor areas for storage in the larger reservoir section. This header section can also supply emergency raw water to the filter plant, the reactor coolant water system, or to the high tanks. The export system header is provided with two surge suppressors which protect the export pipe line from surges caused by the loss of the electric-driven export pumps; these are discussed in detail in Section III.C.2.c, following. The number and location of the various export pumps are shown in the following tabulation.

EXPORT WATER PUMPS

Building	Electric Drive				Steam Drive			
	No. of Pumps	Capacity (gpm)	Head (ft)	Motor hp Rating	No. of Pumps	Capacity (gpm)	Head (ft)	Turbine hp Rating
182-B	5	6000	475	1000	1	6000	475	1000
182-D	2	6000	475	1000	1	6000	475	1000
	2	3000	475	450				
182-F	2	3000	475	450	1	6000	475	1000
182-H	2	6000	475	1000	1	6000	475	1000

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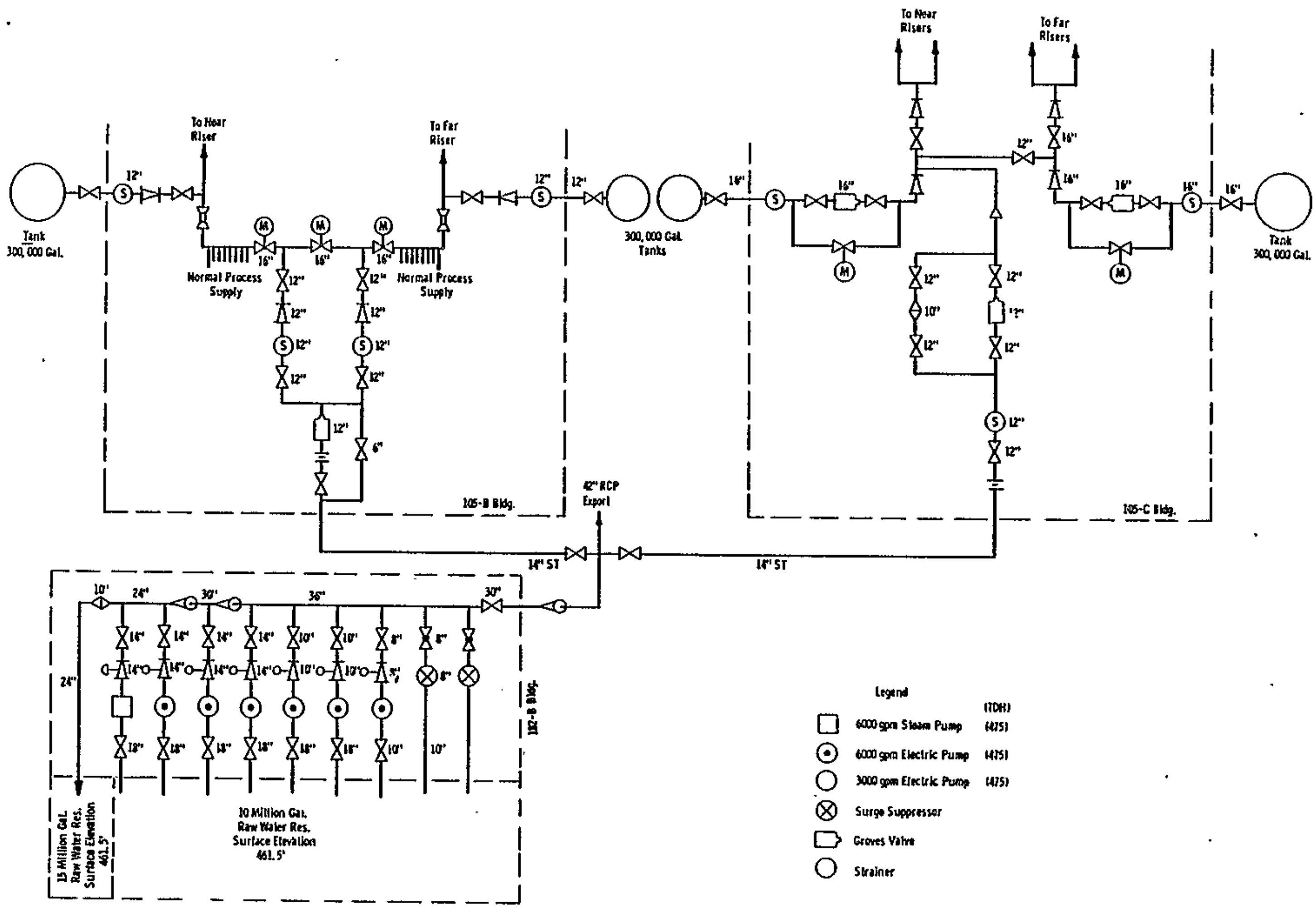

FIGURE III-16

Last Ditch Coolant Piping Schematic, 182-Building to 105-B and 105-C Buildings

b. 105 Building Valve-Pit Connections

The reinforced concrete export water pipe is changed to a smaller size cast iron pipe outside of the 182 Buildings in each reactor area. A steel pipe is used at 182-B and C. These pipe lines enter the valve pits in each reactor building, as shown in Figure III-16. Each of these pipe lines is equipped with a pilot-operated control valve and an orifice designed to limit flow. The operation of these valves is automatic, and hydraulically actuated upon signals received from sensing lines installed in the high tanks and in the reactor cooling water inlet risers. The elevation of the high tank sensing line causes the valve to open about six minutes after the high tanks have started to drain. This time varies at the reactors and is tabulated below:

Reactor	Sensing Line Response Time
105-B	11 minutes
105-C	10 minutes
105-D	5 minutes
105-DR	7 minutes
105-F	4 minutes
105-H	4 minutes

The sensing line in the riser is adjusted to open the valve should the high tank screens become plugged. The trip setting is 36 ± 0.5 psi at the Grove valve, equivalent to 20 psi top of riser pressure, with annunciated high and low alarms set at 55 and 45 psi, respectively. The opening time of the valves is between 10 and 20 seconds as established by throttling the bleed line.

No provision is made for bypassing the export line strainers in case they become plugged. However, in all cases, except at 105-C, two parallel lines are each provided with a strainer so that alternate flow paths are available.

c. Separations Plants Connections

As mentioned previously, the Export System is also used to provide raw water to the chemical processing buildings in the Separations Plants.

An export terminal is provided at the 282-E Reservoir and at the 282-W Reservoir. Flow control for the reservoirs is manual, however, these cone valves are presently being modified to automatically close or partially close within 4 to 12 minutes upon receipt of a signal indicating loss of pressure in the export system or upon loss of electric power in the chemical processing buildings. Valve closure is accomplished with an air-powered hydraulic pump and is independent of external power sources.

d. Surge Suppressors

The 8-inch diameter surge suppressors, installed in the export water header in the 182 Buildings, are provided for the purpose of counteracting the pressure transients caused by failure of the export pumps and to protect the pipe from over-pressure caused by improper operation of the equipment or valves. The transient pressure protection is effectively provided by "anticipation", i.e., operation is initiated by low pressure in the export header caused by the negative-pressure surge which immediately follows pump failure. This causes the suppressors to begin cycling by de-energizing a spring-loaded solenoid. The cycle is completed automatically through mechanical action of controls which are integral with the suppressors and adjusted to open in one and one-half to three seconds and close in two minutes. The maximum discharge per suppressor during a cycle has been estimated as 11,000 gallons per minute.

The pressure trip settings for the surge suppressors are given below:

Export System Surge Suppressor Settings

Pressure Control, Trip	120 psig (B & D) 80 psig (F & H)
Pressure Control, Reset	170 psig (B & D) 190 psig (F & H)
Main Valve Opening Time	1 1/2 to 3
Closing Time	120 ± 10 Sec.
Solenoid Control, Trip	Upon low-pressure signal
Reset	After 60-70 sec. delay
Relief Valve	285 - 295 psig (B & D) 305 - 315 psig (F & H)

The controls provided for surge protection are arranged so that the suppressor will not recycle until the export header pressure equals or exceeds the reset pressure for a period of time greater than 60-70 seconds. This feature is required to prevent unnecessary recycling during a period of approximately six minutes following pump failure, in which the system is unstable due to interaction of surge suppressors in the four limited areas.

The overpressure trip is actuated by a relief valve and is independent of the solenoid. Overpressure will cause a suppressor to cycle at any time that the header pressure exceeds the relief valve setting. A manually-operated glove valve is provided in each surge suppressor line to prevent excessive water loss should a suppressor fail to close.

All of the 182 Building export water pumps can deliver water to the System at the same rated discharge pressure, 475 feet. However, considering both the pipeline capacity and elevation, the 100-B and 100-D Areas are in the most favorable location to supply the daily water requirements of the Separations Plants, see Figure III-15. Consequently, the normal pumping load is carried by the 100-B Area and is provided exclusively by electric motor-driven pumps, the steam turbine pumps being reserved for emergency operation only. In non-pumping areas, the 182 Buildings are not manned by operators and the steam pumps are set to automatically begin pumping within one to ten minutes after the loss of electrical power. This optional delay is provided to control the emergency loading on the boilers in the power house.

D. Water Plant Instrumentation and Control

1. River Pump House - 181 Building

The instrumentation in the River Pump Houses consists of pressure gages on the pump discharge lines and headers, ammeters and voltmeters on the incoming electric lines and an ammeter for each feeder line to the pump motors. Some of the pumps have a thrust bearing temperature gage, and an upper and lower guide-bearing oil temperature gage. The incoming electrical power lines and each of the feeder lines to the pumps have thermal overcurrent relays and either a fuse or an instantaneous overcurrent relay to protect the equipment. The 181-D and the 181-H Buildings also have ground fault protection relays. The ammeters, voltmeter, and relays are located at the switchgear in the building. At the 181-B Building there is also a river water temperature gage.

Motors can be operated manually at all of the 181 Buildings by push buttons at the switchgear. The river pump house motors in the 181-B and 181-D Buildings can be operated from the control rooms in the 183-C and 183-D Buildings, respectively. An annunciator is a part of the supervisory control system and sounds an alarm at the control room in 183-D for a pump motor tripout, a high building temperature, a high river water screen pressure differential, a high bearing temperature, and battery and bus undervoltage. At the 183-B Control Room, the supervisory control annunciator sounds an alarm for a motor tripout, an electric bus undervoltage for the 181-C pump motors and a thrust bearing temperature tripout for the 181-C pumps.

During reactor operation all electric pumps in most river pump houses are required. During a reactor outage, the number is reduced to one, two, or three pumps to satisfy the demand at the reactor. Check valves in the pump discharge piping prevents back-flow through the non-operating pumps.

2. Reservoir and Pump House - 182 Building

a. 182 Inlet House

The flow of water into the 182 Reservoir is regulated by control valves in the 182 Inlet House. Both the 30-inch reservoir lines and the 42-inch line from the primary water system contain cone valves. When the control system is operating automatically the positioning of the cone valves is controlled by the water level in the 182 Reservoir. Normally water flow is regulated by the 30-inch reservoir supply line control valve, which is regulated to maintain a constant level in the reservoir. If the reservoir water level falls below a lower limit, a second control valve in the 42-inch line from the primary water system will also open. As soon as the demand from the 182 Reservoir diminishes to the point where the 30-inch reservoir line can supply all of the water, this second control valve closes. Water flow into the reservoirs is controlled automatically in the 182-B and 182-D Inlet Houses. At the 182-F Inlet House, the flow through the 30-inch line is controlled automatically, but the flow through the 42-inch line is controlled manually. The flow into the 182-H Reservoirs is controlled manually.

b. 182 Pump Room

The instrumentation for the filter supply pump and piping system is limited to two pressure gages on the filter supply header. The incoming electric lines have an ammeter, voltmeter, and instantaneous overcurrent relay. The feeder lines to each pump have an ammeter, a thermal overcurrent relay, and a fused overcurrent relay. The filter supply pumps are used only at infrequent intervals to help supply water to the 183-B and 183-D Filter Plants. When there is a shortage of electrical pumping capacity at the river pump house, due to a pump being down for maintenance or repair, the two steam turbine pumps can be used to pump water to the 182 Reservoirs. One or two of the filter supply pumps are then used to pump water from the 182 Reservoirs to the 183 Filter Plants.

3. Filter Plant and Chemical Treatment - 183 Building

a. 183 Head House

The flow rate from the river pumps to the 183 Filter Plants is regulated at the 183 Head House with a cone valve in each of the two pipe lines to the settling basins. Each of the cone valves has a bypass line with a motor-operated gate valve. The regulation of the cone valve is automatically controlled by the water level in the settling basins. Flow in each pipe line is measured by an orifice located in the head house valve pit.

The instrumentation and controls for the 183 Head House and Sedimentation Basins are mounted on a control panel located in the head house. The control panel contains a flow recorder, a mercury flow gage, and a pressure gage for each of the two inlet lines, a basin level recorder for each half of the basins, a manual control switch and controller for each of the cone valves, and push-button station with lights for each of the bypass valves. At 183-C and 183-D the control panels also contain the supervisory control push-buttons for remotely starting and stopping the electric pumps at 181-B-C and 181-D-DR, respectively.

Each head house contains a laboratory for determining the quality of both the raw and filtered water. The water quality forms the basis for a change in chemical feed and filter backwash cycles.

b. 183 Filter Building

The filter buildings contain the controls and instrumentation for the filters and the filter backwashing system. There is a backwash control panel at each filter in the six filter plants. Each of these control panels contain manual controls for the influent valve, the two effluent valves, the two backwash valves, and a waste valve. A head loss gage and a filter flow meter gage are also mounted on all of the control panels. The 183-H backwash panels do no have flow meters. The valves in the backwash system are hydraulically operated. The backwash period is determined by a combination of water quality, filter flow, and head loss through the filters.

The filter backwash system at 183-C is normally semi-automatic. The backwash process is manually started and will continue automatically until the cycle is completed. The semi-automatic system can be switched to manual at any time allowing the filter backwashing process to be controlled from the backwash control panel, as in the other filter buildings.

The filter backwash system at 183-DR is presently a manual system, but is being modified to make it automatic and similar to the 183-C system.

Each filter building has a water level recorder for each clearwell and a high tank filtered water header pressure gage. The filter flow meters are connected to venturis in the effluent lines of each filter. The flow rate of the filters is normally regulated by a control valve in the filter effluent lines. The valves are positioned according to the water level in the clearwells at 183-B, C, D, F and H. At 183-DR the valves are controlled by the water level in the 190 Storage Tanks.

The 183-DR Filter Room has a control panel with flow dial gages for the two effluent flumes, tank level dial gages for each of the four 190-DR Storage Tanks, a water level gage for the four tanks, a make-up water recorder, a backwash water recorder, and a manual regulator for the makeup water butterfly valve. A large double-face backwash dial gage is also mounted just outside of the control room.

The 183-C Filter Room also has a control panel board with water level gages for the four 190-C Storage Tanks, flow gages for the north and south effluent flumes, water level gages for each clearwell reservoir, a backwash flow gage, a high-tank level gage and a high-tank level pressure gage.

Filter through-put can be increased by raising the water level in the settling basins and by lowering the water level in the clearwells. Either condition increases the available head through the filters. The optimum water level of basins and clearwells varies in the different filter buildings according to which part of the water plant system limits the maximum flow possible.

c. 183 Pump Room

The primary coolant water instrumentation in the 183 Pump Rooms consists of pressure gages on the discharge lines of the transfer, high-tank, and backwash pumps, and pressure gages on the transfer and high-tank pump headers.

The incoming electric lines contain an ammeter, a voltmeter, a thermal overcurrent relay, and an instantaneous overcurrent relay. The feeder lines to the pump motors contain an ammeter, a thermal overcurrent relay, and either an instantaneous or a fused relay.

As at the 181 Building, there are no control valves or flow meters in the 183 pump discharge piping. The water flow is regulated by the control valves in the lines to the 190 storage tanks. Normally all six process pumps are run during reactor operation. During outages the number is reduced to one or two pumps.

4. 190 Building and Pump Annex

a. Water Storage Tanks

Water flow to the 190-B, C, D, F, and H Storage Tanks is regulated by control valves in the storage tank inlet lines. At 190-B, D, and F the control valves are cone valves, at 190-H they are butterfly valves, and at 190-C they are ball valves. The operation of the valves is controlled automatically by the storage tank water level. At 190-DR, the flow is controlled by adjusting the amount of make-up water, supplied from 183-D, added to the effluent flumes.

The instrumentation for the cooling water piping system in the 190-B, D, F, and H storage tank rooms consists of a water level gage board for each tank, a recorder showing water drawdown for each tank, a pressure recorder for the incoming line header, and four pressure gages on the incoming line header--one in the vicinity of the tee for each of the inlet lines to the tank. There is no flow measurement equipment for the piping between the transfer pumps and the primary coolant pumps.

b. <u>190-B, D, DR, F and H Annex</u>

Mounted on the pump and drive unit, or on the instrument panel near the pump are the following temperature gages: the motor inboard bearing, inlet and outlet air to the motors, the motor outboard bearing, the flywheel bearing, flywheel air, the four reduction gear bearings, the pump inboard bearing, the pump outboard bearing, and the pump thrust bearing. Each gage has a high temperature indicator and an electrical contact for the alarm annunciator. A lubricating oil pressure gage is mounted on the pump, and a suction gage is mounted on the instrument panel.

Each pump set has a field control panel in the Annex Pump Room. Each field control panel contains sixteen annunciators with visual signals for high temperature in all bearings, high motor and flywheel air temperature, high motor winding temperature, high and low lubricating oil temperature, and low lubricating oil pressure. Meters on the panel show power factor, AC amperes, DC field amperes, and winding temperatures for the motor. A manual rheostat is provided for control of the synchronous motor DC field. The field breaker, discharge resistors, rotor protection relay, and synchronizing relays provide for completely automatic field application and removal.

There is also a power loss relay and bypass in the 190 Building for each 4500 hp electric motor. These relays monitor input power to the motor and when the power input is below the set value, the relays operate to scram the reactor through the power failure (PF) relay in the 105 Building, to automatically accelerate the emergency steam turbine-driven pumps in the 190 Building, and after a 30-cycle time delay, trip the synchronous motor circuit breaker in order to prevent loss of flywheel energy through regeneration. A typical electric control system used with the electric motors for the primary cooling water pumps is shown in Figure III-17.

An emergency motor control center is located in each of the 190 Annex Pump Rooms for operating the cone valves, the bypass valves, and the electric-driven lube oil pump.

Each cone valve has two motor operators--one for seating and unseating the valve, and one for rotating (open-close) the valve. Pressing the push button for either "open" or "close" automatically starts the valve unseating

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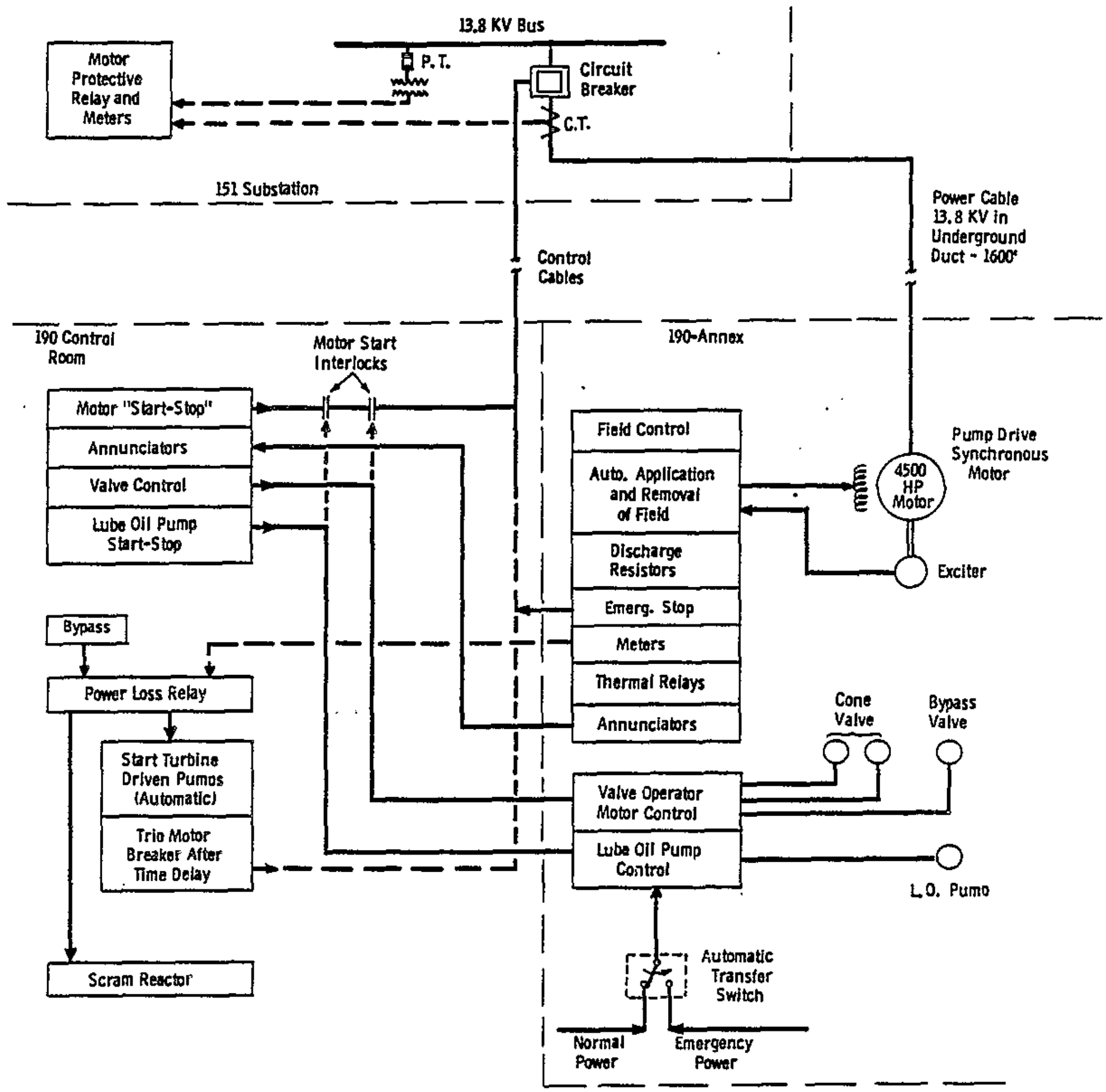

FIGURE III-17

Control System for Primary Coolant Pumps in 190 B, D, DR, F and H Buildings

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operation and sequential open or close operation. Each of the motor operators has valve position indicators. Power is normally supplied from the 151 Substation with automatic transfer to emergency power from the power house turbine-generator.

The operation of the primary coolant pumps is accomplished from the control room panel board which contains all of the controls for the eight pumps and associated valves. The graphic panel shows the following switches, instruments, and indicators for each pump unit: a pump motor breaker control switch (SB-1) and indicator lights; cooling water supply valve operating switch and indicator light; auxiliary lubricating oil pump motor operating switch and indicator light; pump discharge cone valve open, close, and stop push buttons and indicator lights; bypass valve open, close, and stop push buttons and indicator lights; selector switch for individual or group operation of process pump discharge cone valves; pump flow indicator; and pump discharge pressure gage. Also included on the graphic panel is a set of master control push buttons for operating the cone valves. The cone valve is operated from its own push buttons for manual operation. The cone valve may be controlled by the master control push buttons for automatic operation. Any part, or all of the eight cone valves can be operated automatically by the master control, and all eight cone valves can be opened or closed at the same time.

The control panel has 40 visual alarm blocks and a warning buzzer. In the event there is a malfunction on any part of the pump sets, the buzzer sounds and one or more blocks will light up and indicate the offending pump set.

Miscellaneous gages and recorders that are vital to the primary coolant system are also mounted on the control panel. They include a water level gage for each 190 storage tank, the primary coolant pumps suction header pressure gage, the 190 storage tank header pressure gage, emergency filtered water pressure gage, a reactor inlet riser pressure gage and recorder, a high-tank water level gage, and an export pressure gage.

c. <u>190-C Annex</u>

The instrumentation for the 190-C pump drive sets consists of temperature gages and lubricating oil pressure gages mounted on the units. There are temperature gages for the flywheel bearings, the four reduction gear bearings, and the four fluid drive bearings. An oil pressure gage for each of the pressure lubrication systems is also mounted along the side of the pump drive set.

There is a power loss relay and bypass for each 3500 hp electric motor. These relays monitor input power to the motor and when the power input is below the set value, the relays operate to scram the reactor through the power failure relay in the 105-C Building. Undervoltage relays, with bypasses, in the 151 Substation also operate to scram the reactor.

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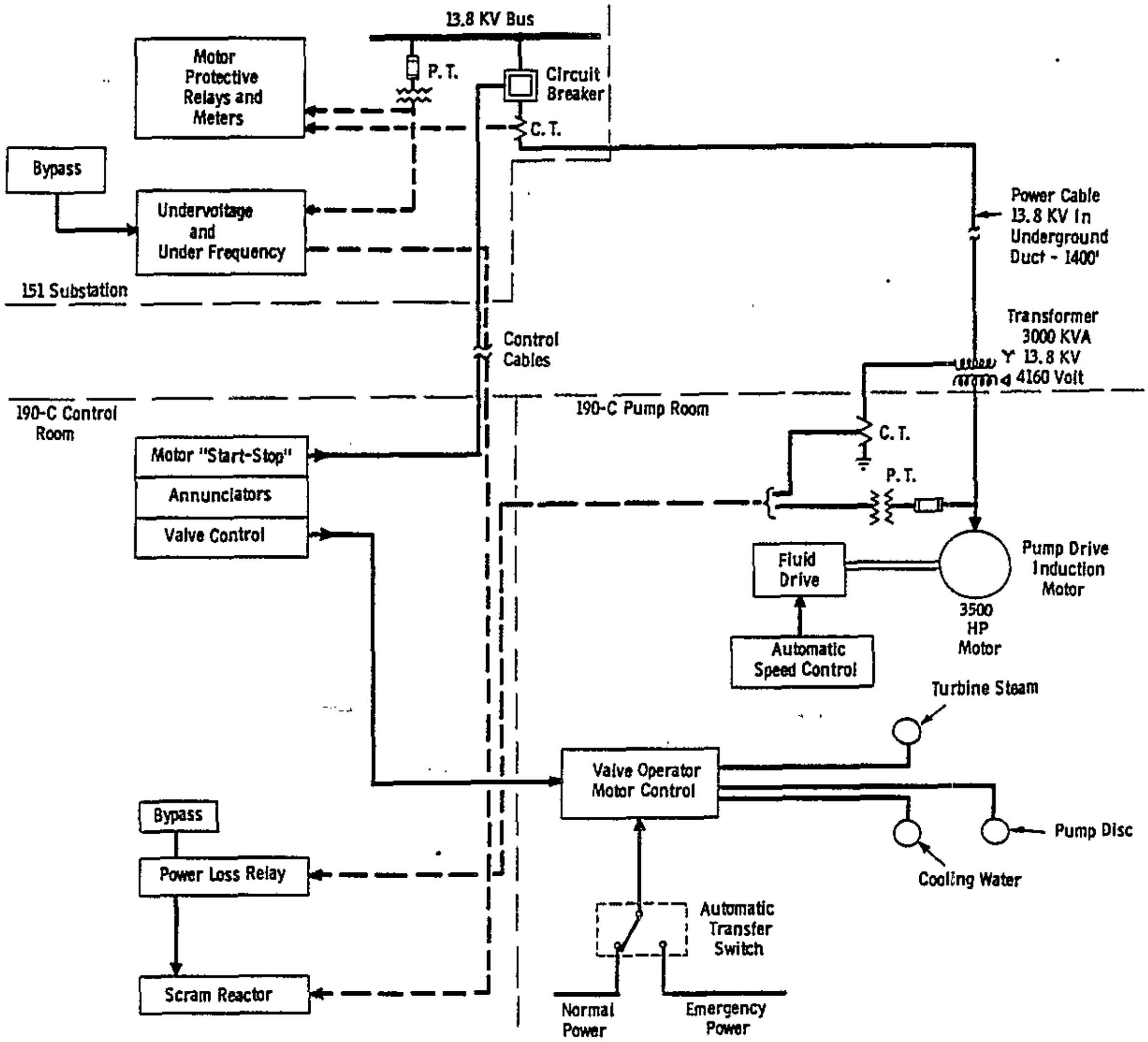

FIGURE III-18

Control System for Primary Coolant Pumps in 190-C Building

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A typical electric motor control system associated with each pump is shown on Figure III-18.

Three motor control centers in the 190-C Pump Room contain the controls for the operation of all motor-operated suction header valves, pump discharge valves, discharge header valves, cooling water valves, and steam supply valves. The operation of the valves is controlled from the panel board in the control room.

The operation of the ten primary coolant pumps and the regulation of the flow to the reactor is accomplished from the control room panel board. Each set of controls consists of: a motor control switch, a turbine control switch, a cooling water valve switch, a pump speed controller, a fluid drive oil temperature gage, a discharge pressure gage, a fluid drive inlet speed indicator, a fluid drive outlet speed indicator, a power loss relay bypass switch, and an AC annunciator.

Other panel boards contain flow gages for each pump, 190 storage tank water level gages, pump suction header pressure gages, reactor inlet riser pressure gages, cooling water pressure recorder, high-tank water level gages, filtered water pressure gages, export water pressure gage, a master control, and a master controller for the individual pump speed controllers.

The speed of the pumps is controlled through the fluid drive and can be done either manually or automatically. Any one of the primary coolant pumps may be controlled manually while the others are controlled automatically.

The speed of all operating pumps is controlled by the master control when the master speed controller and all individual pump speed controllers are set on automatic. The desired top of riser pressure can be set on the master control and the speed of all pumps will be automatically adjusted to produce this top of riser pressure. Within the range of the pumps, the reactor flow can be regulated by the master control. Normally this method is used to regulate the 105-C Reactor cooling water flow.

The discharge line gate valves are not normally used for regulating flow from a pump. When the pump is initially started, the gate valve is closed. When the pump is on the line, the gate valve is wide open.

IV. POWER DISTRIBUTION INTERNAL TO THE AREAS

A. Normal Electric Power System

All normal electric power to the buildings is supplied from the 230 KV Transmission Loop by the 151 Substations located in each area. Basically, there are two separate normal power supplies throughout each area to each building. Normal operation is with bus tie breakers and switches open. Protective relaying is coordinated so that a minimum of equipment is affected by fault conditions, and the dual power supply provides for continuity of power from the normal source upon loss of any single feeder.

1. 151 Building Primary Substations

a. Power Transformers

There are two power transformers in the 100-F and H Areas, three in the 100-B and D Areas each rated 18,750/31,250 kva, 3 phase, single case, 220 kv gr Y to 13.8 kv delta. They supply the two 13.8 kv distribution systems in each area. There are two 2-1/2% voltage taps above and below rated primary voltage. The delta secondary of each transformer is resistance grounded through individual zigzag grounding transformers and resistors to permit high speed ground current relaying. Substation design, with overhead static wires, large ground mat, lightning arrestors, and underground 13.8 kv feeders, provide modern protection to the extent that faults on one 13.8 kv system have no affect upon adjacent systems. A single transformer is adequately rated to supply all shutdown power requirements in an area. When reactors are in operation, the area power demand requires all transformers to be in service.

Power Transformers 220/13.8 KV

BUILDING	TRANSFORMER NUMBER	MAXIMUM RATING kva**	NORMAL OPERATING LOAD kva*	SHUTDOWN LOAD kva
151-B	1	31,250	27,000	
	2	"	27,000	Approx.
	3	"	26,000	5000 kva
151-D	1	"	23,000	
	2	"	23,000	PER
	3	"	29,000	REACTOR
151-F	1	"	18,000	
	2	"	19,500	
151-H	1	"	19,000	
	2	"	19,000	

*Power Factor between 1.0 (Bus #3, 151-D) to 0.96 lag (Bus 1 & 2, 151-B).
**With two sets of fans installed.

b. Switchgear and Bus Arrangement

Figures IV-1, IV-2, IV-3 and IV-4 show the 13.8 kv bus arrangement and the feeders to the buildings. The 13.8 kv switchgear at the primary substation is located inside a concrete block building. Switchgear, including oil circuit breakers, has been in service since plant startup while modern switchgear with air circuit breakers has been installed for the 151-H buses, the No. 3 and 4 buses at 185-B and D, and for the synchronous motors at the 151-B and F Substations. Each cubicle contains switches to control the electrically operated circuit breakers; relays for protection of the bus and feeder circuit, and instruments. Each of the two buses is supplied through multiple cables running from the power transformer outside, through underground ducts, through the basement vault, and to the 2000 ampere incoming line circuit breakers. Outgoing feeder cables are run in underground ducts approximately 200 feet from the substation building to overhead pole lines. Switchgear for the two buses are arranged "back-to-back," and building feeders may be manually switched to be supplied from the alternate bus.

Circuit breakers are adequately rated for normal designed duty.

Duty 13.8 kv	Rating Amperes	Normal Load Amperes	Interruption Rating mva
Incoming Line	2000	700 to 1200	500
Bus tie	2000	Open	500
Feeder	1200	1 to 250*	250**
			500

*Synchronous motor start across-the-line at approximately 1100 amps.
**Oil circuit breakers, OCB's, on all feeders on Buses 1 and 2 at 151-B, D, and F are rated 250 MVA interruption duty. Newer air circuit breakers, ACB's, are rated 500 MVA.

Buses No. 3 and No. 4 at 151-D are located in the substation annex and are operated as one bus serving only the 4500 hp synchronous motors, four in 190-D and four in 190-DR. Buses No. 3 and 4 in 151-B are also normally operated as one bus.

c. Normal Operation

Substation and maintenance personnel perform all switching manually on orders from the central dispatcher located in the 251 Substation. Conditions involving removal of one of the two power supplies to the buses, for maintenance purposes or loss of one or both supplies through fault, are controlled by Critical Power Procedures which permit continued operation of the reactor or require shutdown as the conditions dictate.

All circuit breakers, for the 4500 hp synchronous motors at 190-B, D, DR, F, and H and the 35000 hp induction motors at 190-C, are operated from the control room in the respective 190 Buildings.

d. Relaying

Protective relaying is provided throughout each area in accordance with modern practice for industrial plant electrical distribution systems. In the event of overload or short circuit on the system, these protective devices localize the disturbance by selectively tripping the protective device nearest the source of trouble. Fuse and relay selection, installation, and setting is based on formal coordination studies and is designed to provide maximum protection to systems and equipment from the 200 kv transmission lines down through the 13.8 kv distribution, the 2.4 kv distribution, and the 440 volt building power systems. Typical relays used are tabulated on Page 85.

e. Auxiliary Supply

Two station service transformers, 37.5 kva each in 151-B, D and F, and 300 kva each in 151-H, supply auxiliary lighting, and power to battery chargers in the 151 Buildings. A single 125 v, DC, 60 cell, lead-acid battery with motor-generator charge in each substation provides power to operate all 230 kv and 13.8 kv circuit breakers, indicator lights, and annunciators.

2. 13.8 KV Distribution System

a. Primary Distribution

Overhead primary distribution feeders, 13.8 kv on wooden poles, supply normal power to each of the process buildings.

The two feeders to each building are on separate pole lines to minimize common troubles. Feeders are protected by time overcurrent and residual ground relays.

b. Alternate Lines

At 181-B and 181-D, the capacity of a single line is less than the total load of these buildings. If it is necessary to remove one line from service, an alternate line extension of the 183 Building feeder may be utilized by operation of local, manually-operated pole top switches. The normal feeder to the 184 Building is an extension of either one of the 183 Building feeders in each area.

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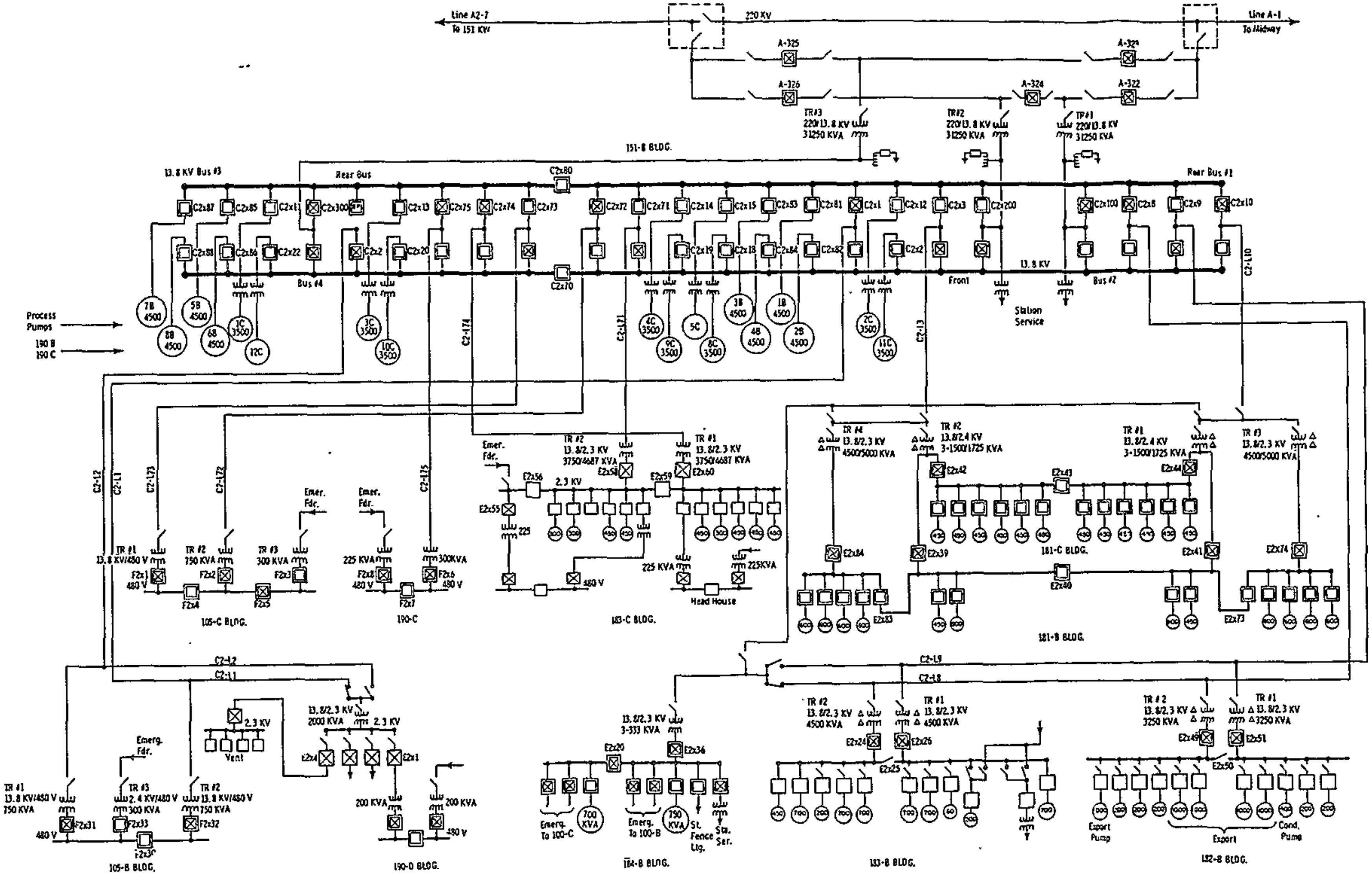

FIGURE IV-1

100-B Area Electrical, One-Line Diagram

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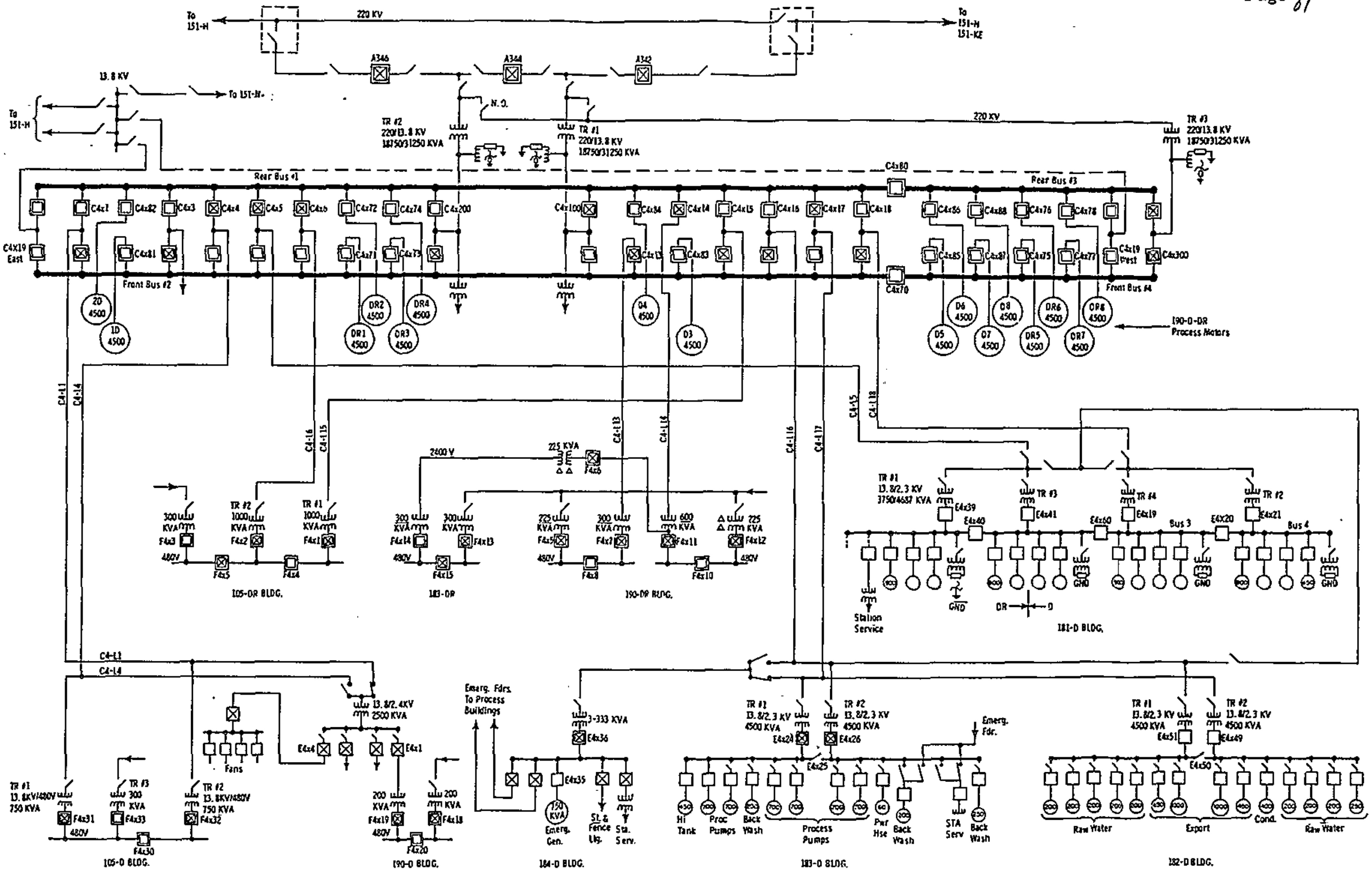

FIGURE IV-2

100-D Area Electrical, One-Line Diagram

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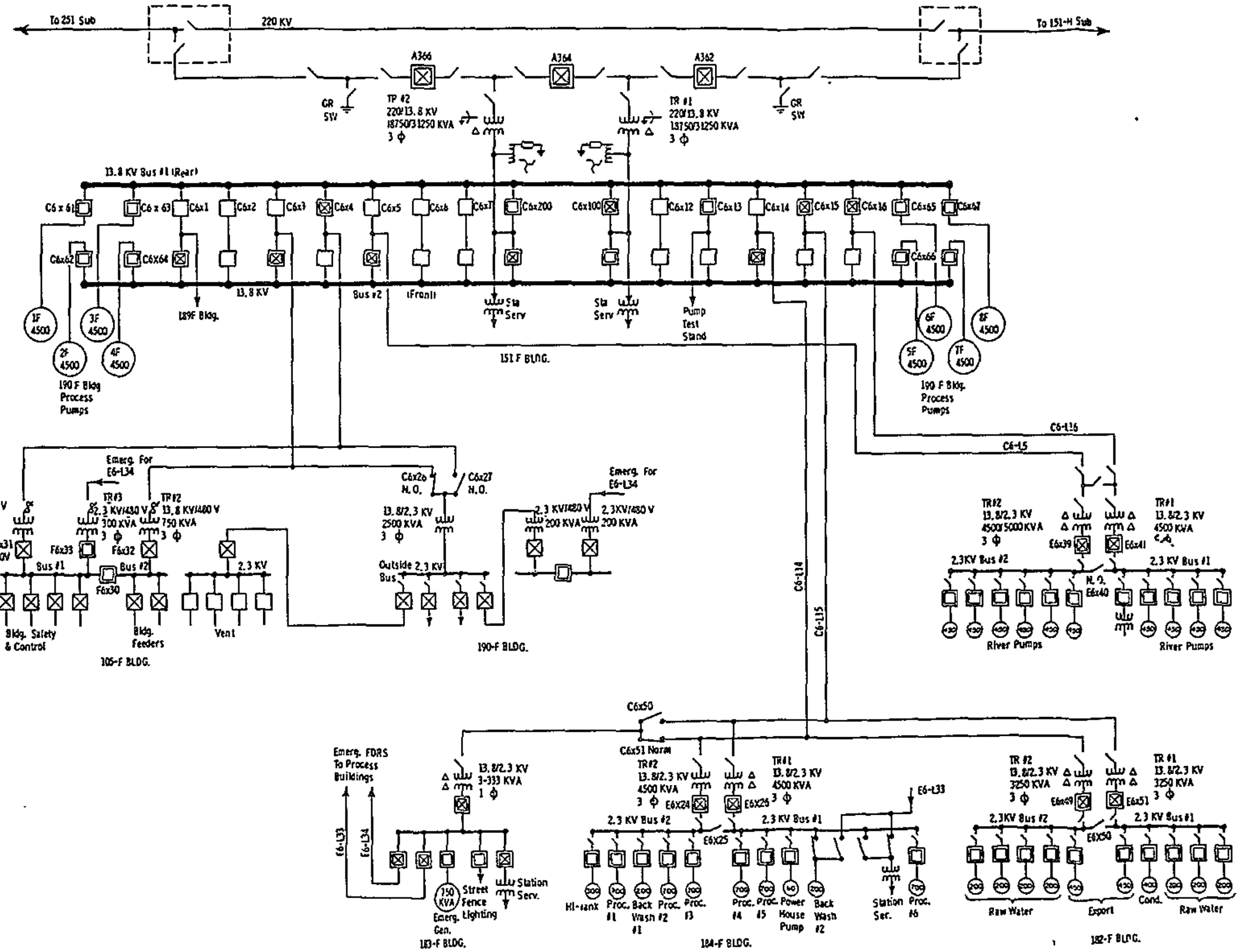

FIGURE IV-3

100-F Area Electrical, One-Line Diagram

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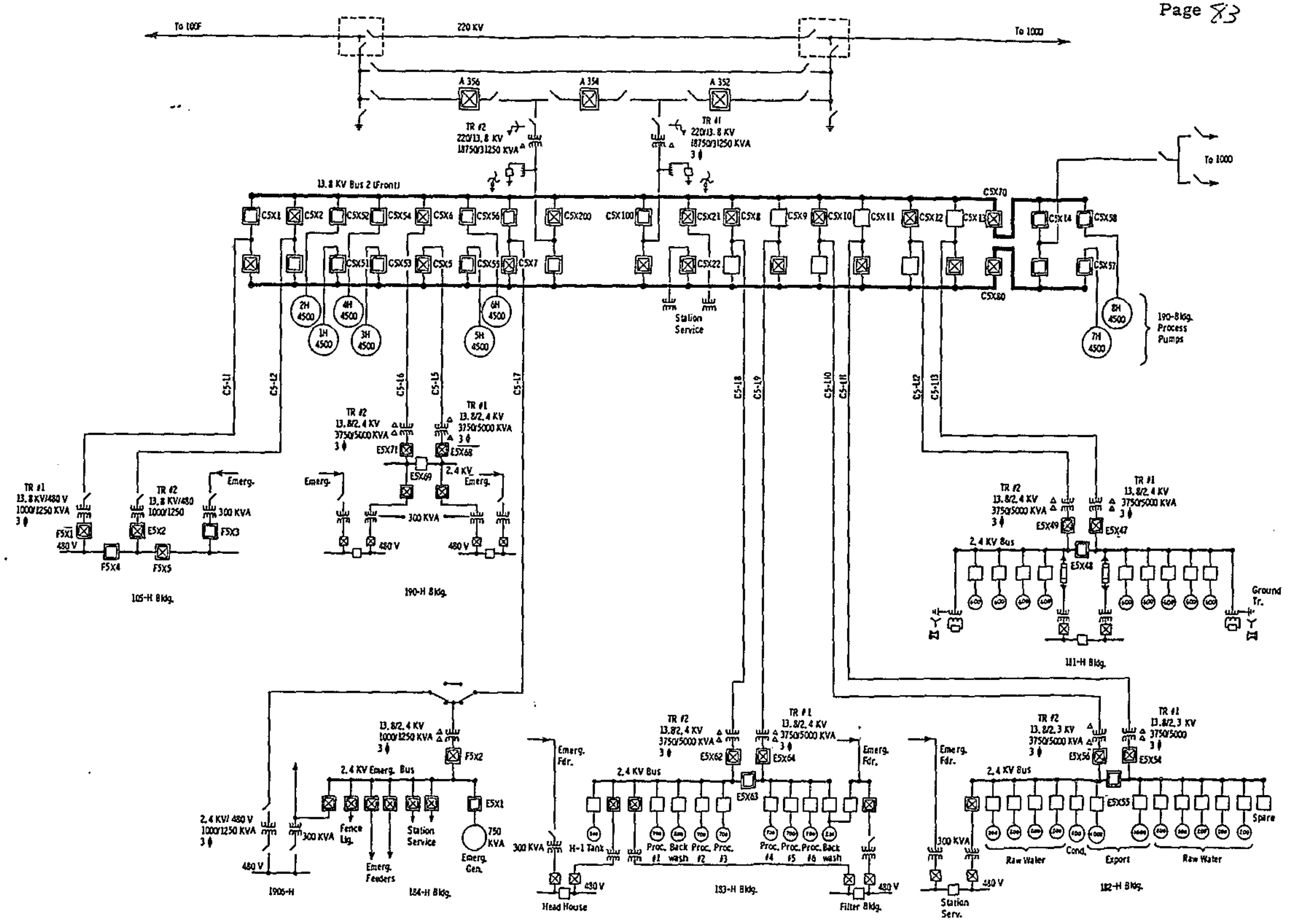

FIGURE IV-4

100-H Area Electrical, One-Line Diagram

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TYPICAL RELAYS APPLIED

151 Bldgs.	Inst. Over-Current	Time Over-Current	(Ground) Residual Overcurrent	Fuse Disconnect	Thermal Over-Current	Remarks
Incoming Line	X	X	X			
Bus tie	X	X	X			
Synchronous Motors (190-B,D,DR F, and H)	X	Annunciate only	X			Plus phase balance, % differential, undervoltage, over-under freq., pullout of step, and field thermal (induction start)
Induction Motors (190-C)	X	X	X		X	Plus phase balance, transformer secondary, and neutral abnormal relay.
Feeders to 13.8/2.4 kv Transformer	X	X	X	X At Transf's		181-182-183 Bldgs. Fuse disconnect plugged.
181-182-183-105						
2.4 kv incoming line	X	X	X			181-D and H buses are resistance grounded.
Bus Tie	(X)	X				
450 - 900 hp motor feeder	X	X	(181-D-H) X		X	
200 hp (182-B,D,F)				X	X	

13.8 KV, 3-Ø DISTRIBUTION FEEDERS

Line No.	Bldg. Served	Capacity Amps	Present Load Amps	Remarks
C2-L3	181-BC	346	230	
C2-L10	181-B/C	346	310	Feeds Midway & Riverland
C2-L8	182,183 & 184-B	346	140	
C2-L9	182,183-B (& 184-B)	346	145	
C2-L71	183-C	185	45	
C2-L74	183-C	185	80	
C2-L1	190-B, 105-B	(300)	(45)	
C2-L2	105-B	(300)	2	
C2-L75	190-C	(185)	7	Underground cable
C2-L72	105-C	(185)	18	" "
C2-L73	105-C	(185)	18	" "
C4-L5	181-D/DR	346	230	
C4-L18	181-D/DR	346	265	
C4-L16	182-183-D	346	70	Alternate to 181-D and 184-D
C4-L17	182-183-184-D	346	160	
C4-L4	190-105-D		1	
C4-L1	105-D		45	
C4-L13	190-DR		1	
C4-L14	190-DR		1	
C4-L6	105-DR		8	
C4-L15	105-DR		15	
C4-L3	186-189-D		2-70	Test
C5-L13	181-H	210	120	Overhead Pre-assembled cable
C5-L12	181-H	210	95	" " "
C5-L11	182-H	(210)	5	" " "
C5-L10	182-H	(210)	10	" " "
C5-L9	183-H	210	85	" " "
C5-L8	183-H	210	80	" " "
C5-L7	184-H (1906-H)	(210)	17	" " "
C5-L6	190-H	200	2	Underground Cable
C5-L5	190-H	200	2	" "
C5-L2	105-H	(150)	20	" "
C5-L1	105-H	(150)	11	" "
C6-L5	181-F	346	105	
C6-L16	181-F	346	90	
C6-L14	182-183-184-F	346	100	
C6-L15	182-183-F (& 184F	346	90	
C6-L3	190-105-F	(346)	65	
C6-L4	105-F	(346)	1	

c. Feeders to 190 Annex Pump Motors

The 13.8 kv feeders to each of eight 4500 hp synchronous motors in each of the 190-B, D, DR, F and N Annexes are three 350 MCM, single conductor, shielded cables run in separate underground ducts from the vault at the 151 Substation to the motor in the 190 Building, approximately 1800 feet away. Separate control cables for motor control, indication and alarm, and for differential relay protection of the motors are run in adjacent ducts. Cable to motors is rated 150 percent of the motor nameplate current of 196 amperes and is adequate for across-the-line start of the motors; i.e., 550 percent current for 70 seconds.

Ten 13.8 kv feeders, from 151-B to 190-C supply ten 3000 kva, 13.8/4.16 kv transformers located just outside the 190-C Building. Each transformer supplies one of the 3500 hp induction motors in 190-C.

Feeder lines to motors in each of the 190 Buildings are divided equally between the substation buses so that the loss of one bus will not cause loss of all 190 process pumps. The 40 synchronous motors at 190-B, D, DR, F and H have continuous ratings of 4500 hp at 0.8 Power Factor with 15% service factor and present loads are between 4750 hp and 5000 hp depending on eight- or seven-pump operation, respectively. At 190-C, the 3500 hp induction motors have no overload nameplate rating, but are operated at approximately five percent above the 3500 hp rating with maximum temperature limits of 103°C (Resistance Temperature Detectors) and with minimum voltage limits (approximately 100 percent voltage) to control temperature in summer months.

3. Building Substations

a. Transformers

Individual substations at each building provide for switching of the primary feeder, and transformation from 13.8 kv to utilization voltages; i.e., 2.3 kv, 480 volt, and 110/220 volt. The main power transformers are 13.8 kv to 2400 volts at all buildings except 105 (480 volt) and the kva rating and loads are tabulated below.

Older transformers at 181-B, D, and F and at 183-B, D, and F were rated 3000 kva when new and were recently uprated to 4500 kva, 5000 kva with fans.

BUILDING SUBSTATION CAPACITY

Bldg.	Quan.	Rating-KVA	Bus 1	Bus 2	Remarks
181-B	2	4500/5170	2490	2490	(Bus 1 and 2)
-	2	---	1230	1230	(Bus 5 and 6)
-	2	4500/5000	2210	2210	(Bus 3 and 4)
182-B	2	2500/3125	2500	2300	(7 - 200 hp motors not used)
183-B	2	4500/5000	2400	2100	
183-C	2	3570	1300	1950	
181-D	4	3750/4687	2475	3300	Bus 3 - 3300 Bus 4 - 2900 (8 - 200 hp motors not used)
183-D	2	4500/5500	2900	1650	
181-F	2	4500/500	2500	1700	(Fan rating on one transformer)
182-F	2	3250	800	450	
183-F	2	4500	2300	2100	
181-H	2	3750/5000	2400	300	
182-H	2	3750/5000	1400	900	(9 - 200 hp not used)
183-H	2	3750/5000	2550	2150	
184-BDFH	1@	3 - 1 - 333	450	--	(At 184-B Bus 2 - 400 kva)
190-105-BDF	1@	2000	1500	--	
190-H	2	3750/5000	200	200	
105-BCDF	2	750	250	150	
105-H	2	1000/1250	220	500	

As the load increased in various buildings in the past eight years, fans were added to some transformers to obtain the higher rating. It is the general practice to maintain normal loads within the rating without fans as load factors are normally greater than 85 percent. When one transformer is taken out of service for maintenance, the fan rating of the remaining transformer(s) at that substation is sufficient to carry all building loads. Spare capacity for export pumping (normal to 182-B Building) is located at 182-D, F and H Buildings.

The major load on the single transformer at 190-B, D and F Buildings is ventilation fans. New transformers have been installed at 105-B, D and F and they are oversized for anticipated future loads at these buildings.

b. Incoming Line Feeders

The 1200 ampere, 2400 volt, incoming line cables are three 500 MCM per phase at 182-B, D and F and at 183-B, D and F. Incoming cables to the 181 Buildings are run in underground conduit. At the 181-H, the 183-H, the 105-B, D, D, DR and H Buildings, the incoming 2400 volt feeder is a bus duct.

c. Switchgear

There are two 2400 volt switchgear buses (1200 ampere) in each of the 181-F and H, the 182-B, D, F and H, and the 183-B, D, F and H Buildings. At 181-D there are four buses, and at 181-B and C there are six buses. Each bus has an incoming line oil circuit breaker (1200 ampere), a bus tie switch or breaker, and one feeder oil circuit breaker for each motor (60 to 1000 hp) served directly at 2400 volts. Switchgear at 181-D, 181-H, 182-H, and 183-H Buildings has a DC battery for control while at 182-B, D and F and at 183-B, D and F, the breakers are AC controlled with capacitor shunt trip. Ammeters and voltmeters are provided to indicate bus voltage and current on each feeder. Time overcurrent and instantaneous overcurrent relay protection is provided. At 181-D and 181-H, the buses are resistance grounded through "Y-Delta" grounding transformers and ground relay protection is provided.

Where pump equipment is located away from the switchgear, the "start-stop" electrical switch is located near the pump motor. Incoming line, bus tie, and station services breakers and switches are controlled at the switchgear. At 181-B and C, a supervisory control system, which was originally installed to "start-stop" twelve 181-C motors from the 183-C head house has been reactivated and extended to control all 24 motors at 181-B and 181-C from the 183-C Head House. At 181-D, an auxiliary remote control system has been installed to allow "start-stop" control of the 15 river pumps from the 183-D Head House, and undervoltage annunciation, bearing temperatures, screen differential pressure, and motor trips are also provided to the 183-D control panel.

The 2300 volt switchgear at 182-B, D, F, and at 183-B, D and F, and at 181-F is operated 2400 volt undergrounded delta. While the breakers have adequate load and short circuit current rating, available short circuit 39,500 kva - 183-B, the bus tie switches are not load break rated. One bus must be de-energized to operate the bus tie switch.

B. Emergency Electric Power Systems

1. Power Source and Generation

A steam turbine-driven electric generator, 750 kva, 2300 volt, three-phase, is located in each of the 184-D, 184-F, and 184-H Buildings and two generators are in 184-B. These units are normally at standstill and are manually preset to start automatically and assume emergency bus load upon loss of the normal power supply. The 2400 volt bus at the 184 Building is normally supplied from three 333 kva transformers, 13.8 kv to 2400 volt, on a feeder from the 151 Substation. Four outgoing feeders from the emergency bus serve the 184 Building auxiliaries; e.g., lighting, air compressor, coal conveyors, water softener equipment, and ash and sluice pumps, the 2300 volt feeder for power lighting to the 105, 108, 115, 189, 190, and 1700 Buildings, the 2300 volt feeder for power and lighting to the 182, 183 Buildings, and the security fence and street lighting. Upon loss of normal power supply to the bus, undervoltage and/or lighting. Upon loss of normal power supply to the bus, undervoltage and/or underfrequency relays trip the incoming line oil circuit breaker and trip open the solenoid-operated steam valve to start the turbine generator set. It requires approximately twelve to fifteen seconds for the generator to come up to speed and assume the load.

Frequency and voltage relays are set to automatically close the generator oil circuit breaker to energize the bus as soon as the speed and voltage are normal.

The turbine speed is governor-controlled at 3600 rpm, and an automatic voltage regulator controls the generator voltage as preset on the manual rheostat control.

The generators are protected by differential relays and loss of field relays. The turbine speed is governor-controlled with mechanical and electrical overspeed trips.

2. Power Ratings and Load

Figure IV-5 is a one-line diagram of a typical 2400 volt emergency distribution system. Operating load on the emergency bus is approximately 240 kva (days) and 300 kva (nights), with street and fence lighting. The incoming line transformer is 1000 kva, three-phase, and is capable of carrying normal and/or emergency loads. Emergency load pick-up by the generator upon loss of the incoming line supply is approximately 450 kw (500 kva). The increased load on emergency pick-up is occasioned by automatic transfer switches in the 105 and the 190 Buildings.

Total connected load transformer ratings is approximately 3000 kva, but these are not fully loaded. Significant diversity exists between loads such as power house sluice pumps, coal-handling equipment, 190 valves, and air compressors.

3. Building Transfer Switches

The 480 volt "emergency bus" at the 105 Buildings is operated with normal supply from the 151 Substation source and with the emergency incoming line breaker open. Upon loss of normal supply to the emergency bus in 105, the normal incoming line breaker is tripped by undervoltage relays and the emergency feeder breaker closes automatically to supply power from the 151 Substation through the 184 Building emergency bus to the 105 Building. Transfer is delayed several seconds to override system transient conditions. Upon loss of normal power at the 151 Substation bus (loss to both 105 and 184 Buildings), the incoming line breakers to 105 Building may remain closed until the emergency generator energizes the 184 buss, at which time the transfer will proceed at the 105 Building.

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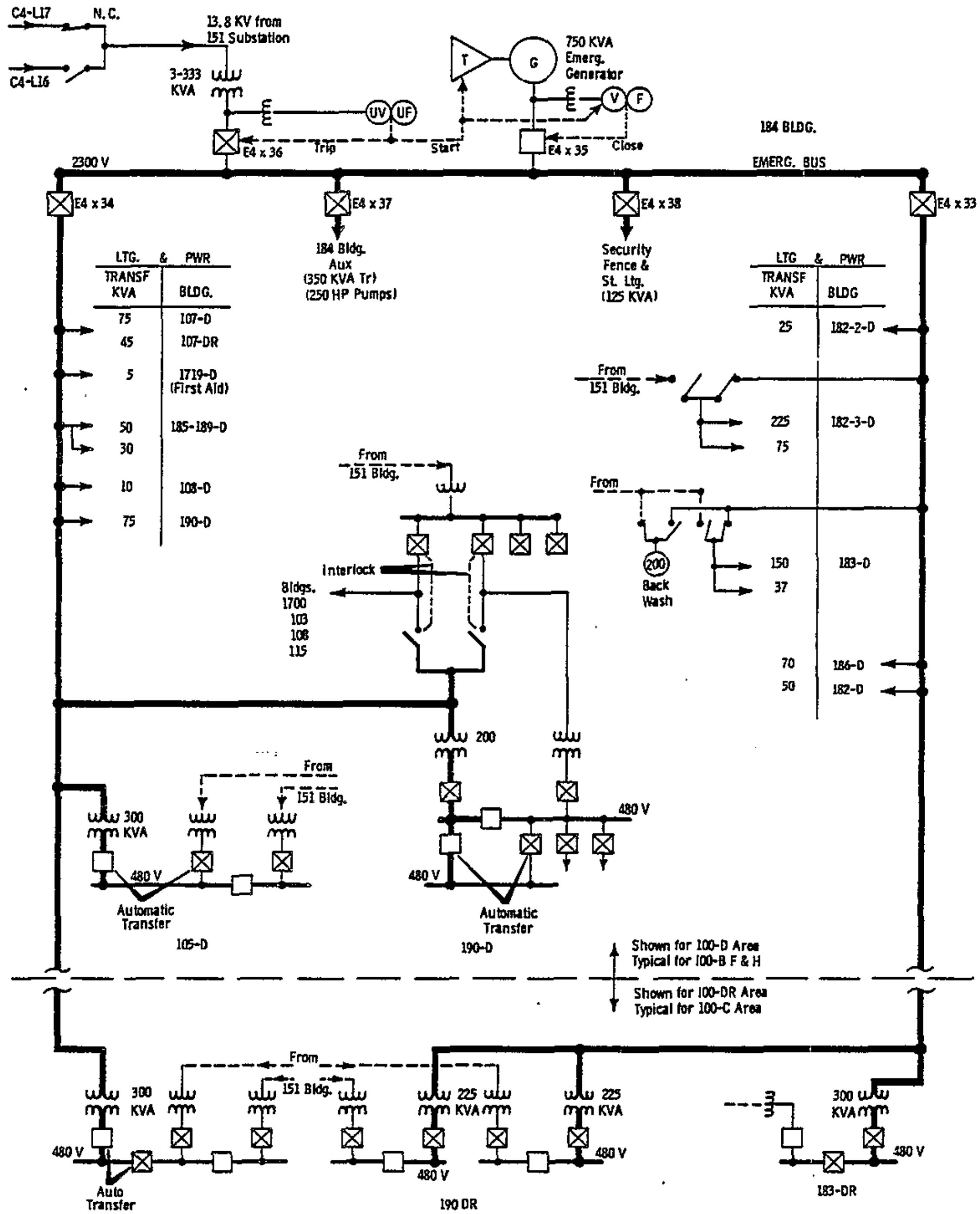

FIGURE IV-5

Typical 2300-Volt Emergency Electrical System

Necessary instrument systems and part of the lighting throughout the building is supplied from the emergency 480 volt bus at 105.

The 480 volt emergency power bus at 190 Buildings is supplied from the normal source through two transfer breakers. Upon loss of the normal source, the transfer to the emergency feeder as a source is automatic. Cooling water valves, lubricating oil pumps and a part of lighting throughout the building are supplied from the emergency bus.

All 184 Building electrical auxiliaries are normally supplied from the emergency bus, and may be operated with the emergency generator as a source. The emergency lighting at 182 Buildings is operated from the emergency source and may be manually switched to the "normal" bus. Backwash pumps at 182 Buildings may be manually switched to the emergency source. There is no emergency feeder to the 181 Buildings.

A nominal amount of emergency power is supplied to service buildings.

V. REACTOR AND BUILDING

A. General

The arrangement of a reactor building, typical of the 105-B, D, DR and F Buildings, is shown in Figure V-1. The 105 Buildings for the C and H Reactors are similar except that the ventilation fan room wing is located opposite, and in line with, the outer rod room wing rather than in the forefront of the building as shown in Figure V-1. The fan room wing of the 105-H Building also contains the reactor gas system, which is housed in a separate building (115) at the other reactors.

The arrangement of the reactor and its control facilities is the same in all of the reactor buildings. The charging face, or front face, of the reactor faces the cooling water pump room, or the 190 Building. Two underground reinforced concrete tunnels connect the two buildings and serve as the pipe run for the reactor cooling water system. The horizontal control rods enter the left side of the reactor, when facing the front face, with the control room located beneath the horizontal control rods. Experimental test holes are located in the right side of the reactor. The fuel discharge area and the storage area are located behind the reactor outlet face, rear face, and are inter-connected via an underwater chute.

The 105 Reactor Building wall construction, typically, is reinforced concrete in the lower portions of the building with concrete block at 105-B, D, DR, F and H, and corrugated asbestos-cement siding at 105-C for the upper portions of the building. The reinforced concrete walls serve as shielding walls and vary from three to five feet thick, depending upon their location. Roof construction varies from precast concrete roof tile at the 105-B, D, DR and F Buildings, to poured insulating concrete in the 105-C and H Buildings. The roof construction over the inner rod room and the rear face enclosure is reinforced concrete. Door construction is generally light and the reactor buildings in general can be classified as light, non-airtight industrial buildings.

The ventilation system in the 105 Buildings serves a twofold purpose. It provides ventilation for personnel comfort and also controls the potential spread of radioactive contamination in the building. Ventilation air is supplied directly to all parts of the building. The control room has a separate refrigerated air conditioning system. In the service and office areas of the building, the air is exhausted through roof ventilators. Air from the potentially contaminated areas surrounding the reactor is exhausted by fans through particulate and charcoal filters, and then into a 200-foot high reinforced concrete chimney to the atmosphere.

Air pressure in the office and service areas of the building is maintained at 0.01-inch water gage, slightly above atmospheric. In the potentially contaminated areas surrounding the reactor, slightly below atmospheric pressures are maintained.

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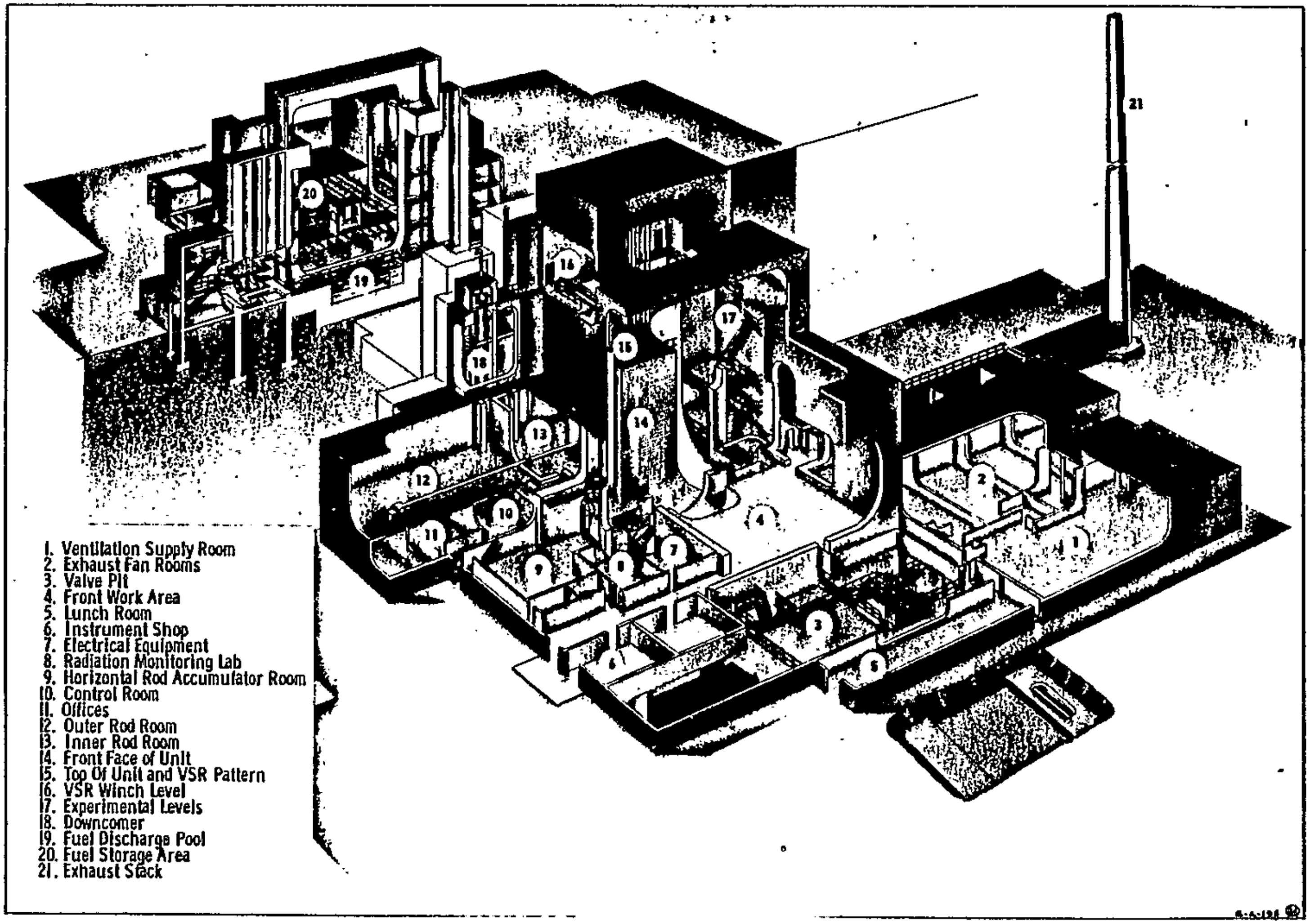

FIGURE V-1

Typical 105-Building Layout

B. Graphite Moderator Stack

The nominal over-all graphite stack dimensions for the B, C, D, DR, F and H Reactors are: front to rear - 28 feet, top to bottom - 36 feet, and side to side - 36 feet. The stack is made up of graphite blocks 4-3/16 inches square by 48 inches long, nominal dimensions.

The graphite used is classed nuclear grade and is manufactured with special care being taken to exclude impurities that have significant neutron-absorption cross-sections. Various purification techniques, derived from processes employed in the production of spectrographic-arc carbons, have been introduced to achieve purities of 99.99 percent carbon.

All commercially produced carbons are composed of a carbonaceous filler material bonded by a carbonized binder. Nuclear grade graphite is produced from a superior grade petroleum coke and a coal-tar pitch. The final step in the manufacturing process requires heating at temperatures above 2500°C to achieve graphitization. The graphite blocks in the B, D, and F Reactors were so processed. The graphite blocks used in the C, DR and H Reactors were graphitized in a Freon furnace-atmosphere so that trace metals in the coke and pitch would form a fluorine salt, decompose at the high temperature and be removed in the furnace exhaust gas. A graphite block of high nuclear purity resulted.

The graphite is stacked in layers with the long dimensions of the blocks parallel within a layer and at right angles to the long dimension of the blocks in the adjacent layers. Block joints in the graphite layers are staggered to provide for greater stability in the stack. This staggered joint pattern is obtained by substituting shorter graphite blocks, for the normal 48-inch blocks, at certain locations in the layers. The bottom graphite layer rests on a carefully leveled surface made up of cast iron blocks, which are used as a thermal shield. These, in turn, are laid in grout on top of a massive concrete foundation prepared for the reactor. Alternate blocks in the front to rear layers are pierced for process tubes, giving a total of 2004 tubes in each reactor. Process tubes are, therefore, located in a square array, or lattace, with a spacing of 8-3/8 inches from center to center of the tube channels.

The criss-cross stacking arrangement of the graphite blocks results in the stack being relatively stable against mechanical distortion. In addition, the graphite blocks are further restricted from movement by keying systems in both the horizontal and vertical direction in the stack, made from the same graphite blocks. The horizontal keying system across the inlet and outlet faces of the graphite stack is essentially similar for all of the reactors, however the vertical keying system has been changed with each succeeding reactor design in an effort to reduce block shifting. The various methods of keying are shown in Figures V-2, V-3, V-4 and V-5.

The design of the "tube" and "filler" blocks has also changed with each succeeding reactor design to overcome channel distortion in the stack.

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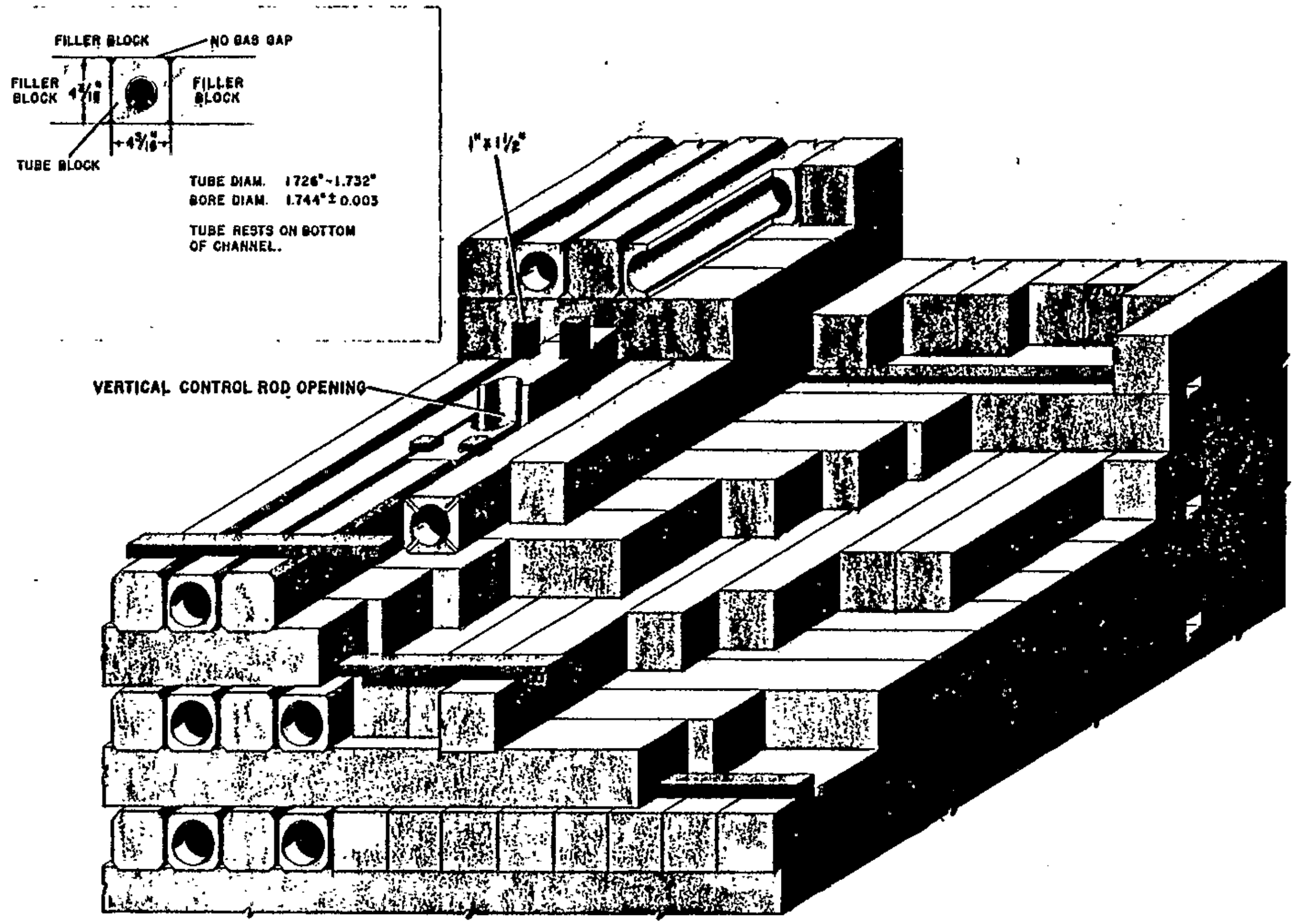

FIGURE V-2

Graphite Stack Keying, B, D, and F Reactors

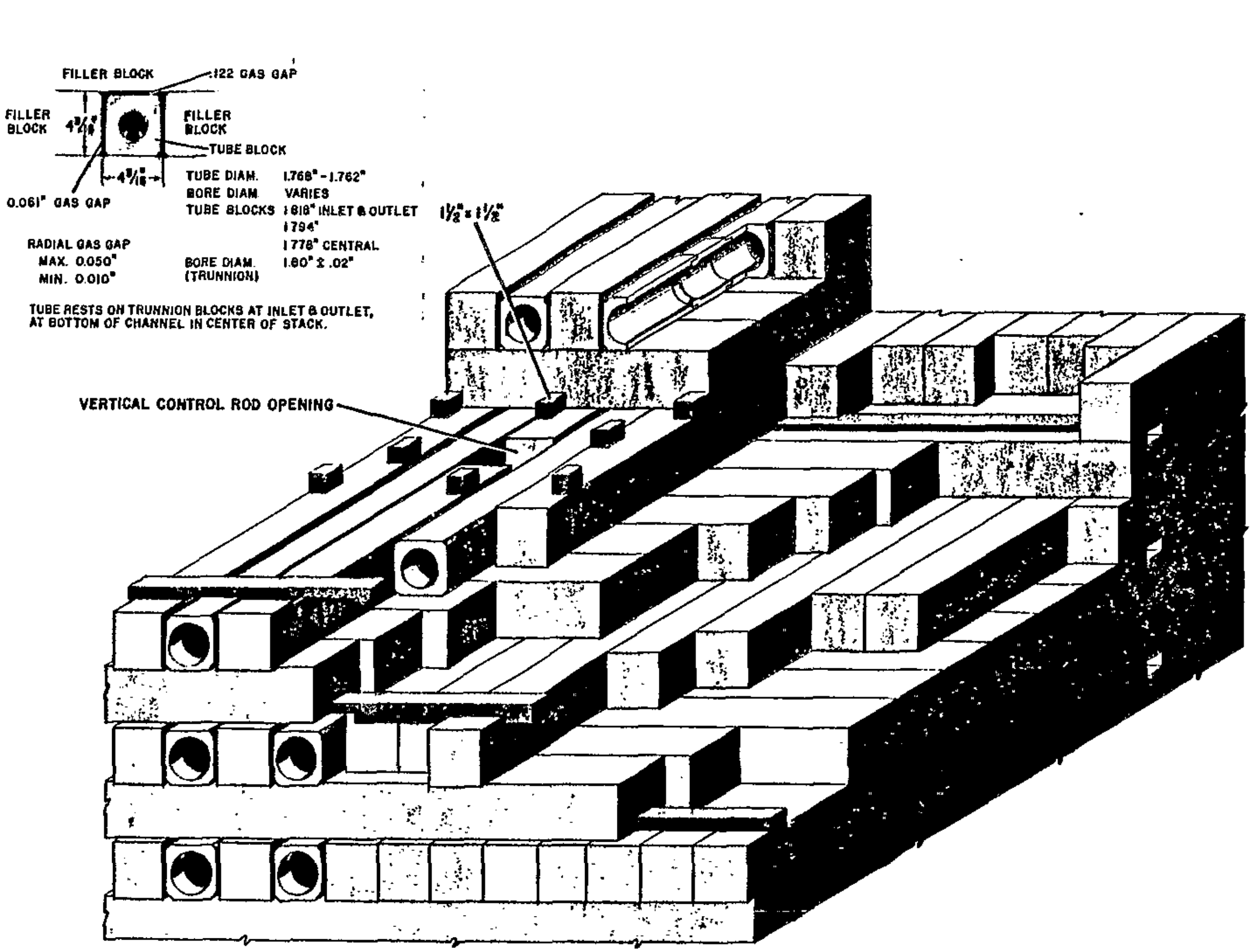

FIGURE V-3

Graphite Stack Keying, C Reactor

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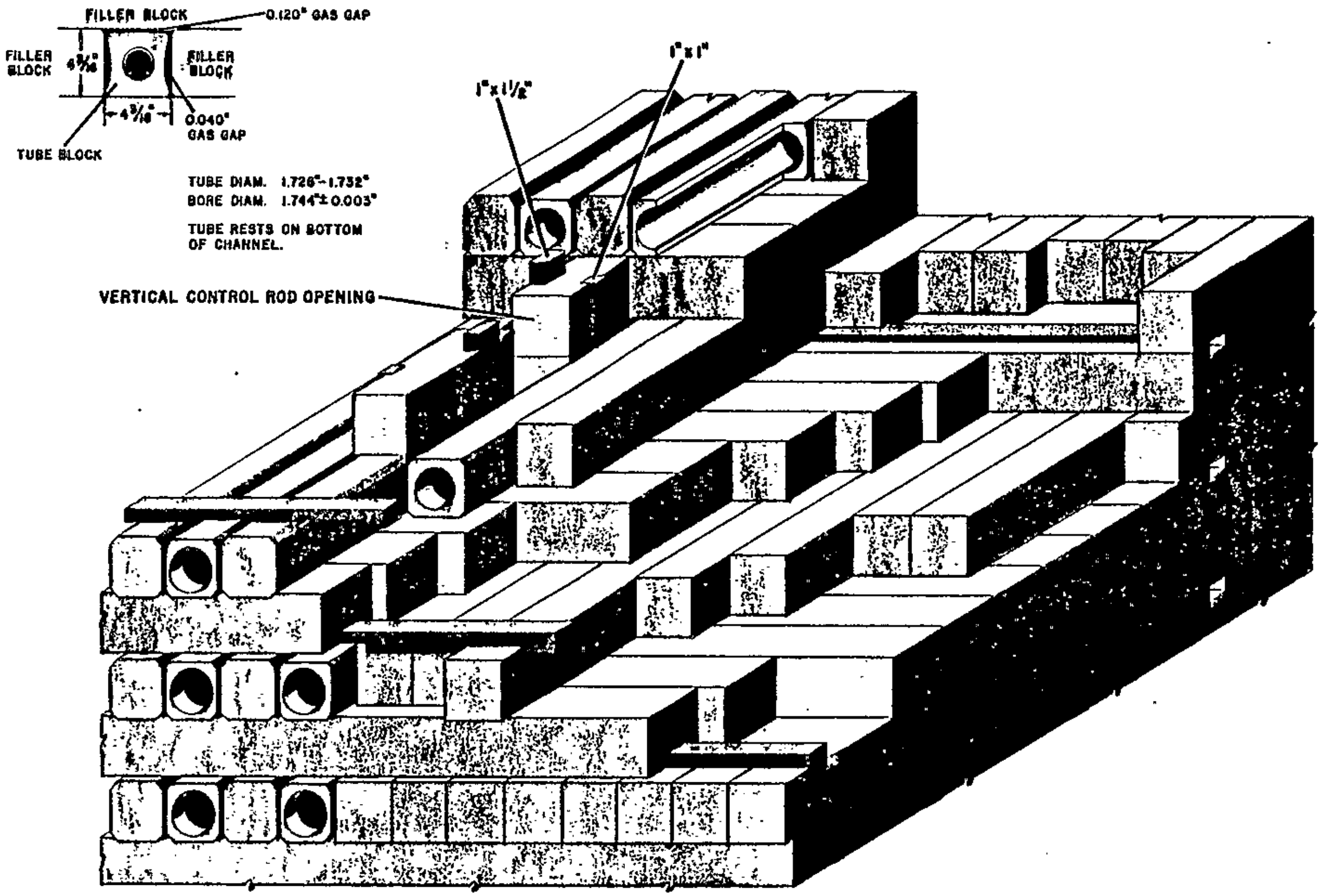

FIGURE V-4

Graphite Stack Keying, DR Reactor

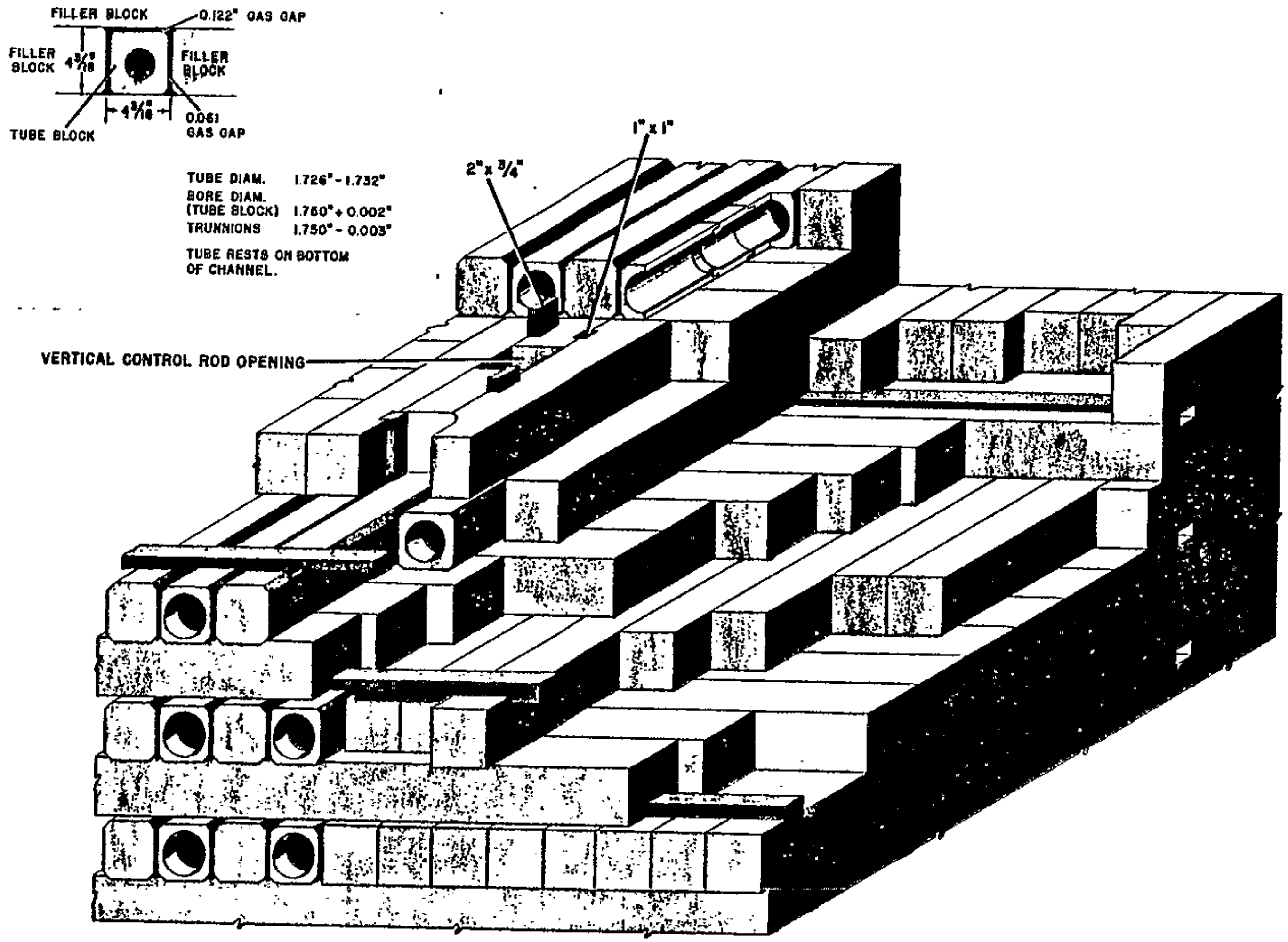

FIGURE V-5

Graphite Stack Keying, H Reactor

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Reactors and forty-five in the C and H Reactors.

2. Horizontal Control Rod Channels

These penetrations are located on the left side of the stack when facing the front face and estend through the process tube pattern in the stack. There are nine horizontal rod channels in the B, D, DR and F Reactors and fifteen in the C and H Reactors.

3. Experimental Test Holes

These penetrations are located in the right side of the reactor and are similar to the horizontal control rod channels. Some of the channels extend through the stack while others extend only into the core of the stack. Six test holes were provided in the B, D and F, seven in the DR, ten in the H, and fourteen in the C Reactors. These test holes are shown graphically in Figures XI-4, 5, 6, 7 and 8 and are described in Section XI.

4. Monitoring Penetrations

Instrument monitoring penetrations are located throughout the stack. The locations are described in the reactor control instrumentation section of this report.

D. The primary objective in reactor shielding is to ensure to operating personnel that exposure to radiation will not exceed long-term tolerance limits. Personnel is assured of this by a combined thermal and biological shield designed after determination of the bulk attenuation characteristics were predicted on the basis of iron-paraffin combinations and converted to iron-masonite full shield thickness by Fermi and Zinn in 1943.

1. Thermal Shield

Between the graphite stack and the outer biological shield is a layer of cast iron, designated as the thermal shield. The thickness of this shield varies by its location. Its thickness is 8-1/8 inches on the top, 8 inches at the sides, 10 inches in the front and rear, and 10-1/4 inches in the bottom. Approximately ninety-seven per cent of the gamma energy radiated from the stack is absorbed in this shield and converted into heat in the cast iron. The thermal shield is built of blocks which overlap each other at the edges so that no crack passes straight through. This feature contributes substantially to the effectiveness of the shield by eliminating the possibility of thermal "hot spots" in the biological shield or in the concrete base.

Cooling is provided for the top, bottom, and side shield by circulating water tubes imbedded in the blocks. The front and rear thermal shields

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VIII. REACTOR INSTRUMENTATION

A. General

There are three basic classifications of instrumentation within the reactor building.

The first can be defined as Reactor Safety Circuit Instrumentation. Instruments in this classification provide information on the status of the process by visual readout devices and are connected directly into the reactor safety circuits for automatic shutdown if established limits are exceeded.

The second is Reactor Process Control Instrumentation. These instruments provide information to operating personnel, as do those in the first classification, but do not have trip-out devices in the reactor safety circuits.

The third classification is Non-Process and Building Environmental Instrumentation. These are instruments used in the control of operations other than those directly affecting the operation of the reactor. They are located throughout the reactor building, in secondary functions such as monitoring radiation levels.

The important instrument characteristics and the important interlock and bypass conditions for safety circuits are tabulated at the end of this Section.

B. Reactor Safety Circuits and Safety Circuit Instrumentation

There are three separate and complete safety circuits in each reactor as shown in Figure VII-1. Each circuit is designed to initiate the insertion of a certain amount of negative reactivity into the reactor, either when the reactor exceeds preset limits or when a failure occurs within the circuit itself.

1. The IX Safety Circuit and Associated Instrumentation

The IX Safety Circuit is designed to scram the Vertical Safety Rods (VSR) and through an interlock, the SN relay, the Horizontal Control Rods (HCR). This is designated a Number One Scram. Only the negative reactivity of the VSR's is counted upon for reactivity control for this safety system. The safety circuits at the B, D, and F Reactors are 120-volt, AC circuits, while the C, DR, and H Reactors have 125-volt, DC circuits. In most arrangements, exceptions being noted in subsequent paragraphs, relays are used in parallel, with contacts connected in series to provide high reliability to trip on demand.

a. Manual Trip

A manual scram pushbutton is located on the reactor control console and is readily accessible to the reactor operator.

b. Grey splines are used to increase flattening efficiency. These splines are only about 58 percent as effective as a regular spline and contain only about six percent B_4C.

c. Half splines contain about 15 percent B_4C in the downstream 19 feet of the spline. The remainder of the spline contains no poison.

d. Flux monitoring splines are a special purpose spline, 0.040 inches thick, which are inserted in the reactor for about 15 minutes in order to determine the flux distribution pattern from activation readings taken during their withdrawal.

The splines are utilized in conventional, ribbed, aluminum process tubes fitted with special inlet caps which allow for spline insertion and removal during reactor operation. The spline inserter is manually operated. Splines are removed with a spline coiler wihch is operated remotely from a radiation shielded area. The spline coiler removes splines at a maximum speed of 300 inches per minute which amounts to a change of 0.02 percent $\Delta k/k$ in 1.2 minutes and deposits the coiled, "hot" spline in a cask of water or into the water filled C work platform pit.

E. Gas Atmosphere

1. General

The purpose of the gas system is to provide an inert, non-radioactive gas environment in the reactor to remove moisture and foreign gases from the reactor; to serve as the heat transfer media between the graphite and process tubes for the removal of heat from the graphite; and to detect water leaks within the reactor.

The reactor atmosphere is a mixture of helium and carbon dioxide with the composition varied and regulated to control graphite temperatures and reactivity requirements during operation. The purity of the gas mixture is also controlled to avoid detrimental effects of foreign gases such as oxygen and water vapor.

The gas system consists of equipment and piping located in the 105, 110 and 115 Buildings and in shielded connecting tunnels. The storage area, 110 Building, contains the high pressure and low pressure storage facilities for helium and carbon dioxide. The 115 Building contains the circulating gas blowers, silica gel dryers, filters, heat exchangers, valves, instrumentation and piping. The gas distribution manifolds, sampling lines, purge lines, and gas analytical equipment are located in the 105 Building. In the 100-H Reactor Plant there is no 115 Building and the equipment is located in the gas wing of the 105 Building. The volume of a closed loop reactor gas system is about 25,000 cubic feet.

Only the 100-B, D, F and H Reactor Plants have gas storage facilities, (110 Buildings). The C Reactor gas system is supplied by the B Reactor storage facilities, and the DR Reactor gas is supplied by the D Reactor storage facilities. Figure V-6 is a flow diagram of a single reactor gas system and Figure V-7 shows a flow diagram of a dual reactor gas system.

The water leak detection system of the reactor gas systems consists of 100 sampling tubes spaced evenly on the discharge face of the reactor and located in the gas plenum between the thermal and biological shields. Water from a leak within the reactor flashes into steam and is removed from within the reactor by the flowing gas stream. The location of the leak is then determined by measuring the water vapor in the 100 gas sampling tubes. Drip legs are also provided in the low points in the loop piping to remove liquid water which condenses from the gas stream. The seriousness of a leak can be determined by the rate at which water is collected in the drip legs. This water plus the water collected in the dryer beds following process tube leaks provides an estimate of how much water entered the graphite stack.

2. Operation of the Gas System

Carbon dioxide is received in liquid form and is transferred to liquid high pressure storage at 325 psig. The low pressure storage tanks at

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100 psig supply make-up system, through a pressure reducing valve, to the circulation system.

Helium is received by railroad tank cars at 1800-3600 psig, and is unloaded through a pressure reducing valve which reduces the pressure to 700 psig. The cascade method is used for unloading; that is the storage tanks with the highest pressure are loaded first. When the pressure in the railroad car tanks is reduced to the storage tank pressure, a helium compressor is used to unload the remaining gas. The helium is transferred from the high pressure tanks to the 50 - 100 psig storage tanks. Through another pressure reducing valve the reactor gas circulation is supplied with make-up and purge gas at 1 to 30 inches water gage pressure.

The circulation system is a closed loop as shown on Figures V-6 and V-7. The flow through the system varies from a minimum of 100 cfm dry, 400 cfm wet, to a maximum of 1800 cfm, the capacity of the blowers. The gas pressure in the reactor is kept at the minimum positive value which will assure circulation and avoid in-leakage of air. The average pressure is less than 1-inch of water, and at normal flows, the pressure at the rear face outlet is 0.01-inch of water.

The gas system is protected from excessive pressure, or suction, by large liquid seal chambers connected to the recirculation lines. The pressure seal tank is set to relieve at 30-inches of water. The gas vented from this seal passes into the underground ventilation tunnel which leads to the exhaust stack. The liquid suction seal is set at minus 10-inches of water to protect the system in case the make-up valve fails to open.

The gas enters the reactor from a gas manifold beneath the unit through risers to the gas space between the thermal and biological shields on the front face. The gas flows through the reactor from front to rear through spaces in the graphite. The gas leaves the reactor through risers and a manifold similar to the inlet side. From the manifold the gas flows through a gas header in the gas tunnel to the 115 Building. A blower forces the gas through a heat exchanger where it is cooled before going through the silica gel dryer. After the dryer, the gas is filtered through the Airmat-type filters to remove foreign particles and any silica gel that is carried over. From the filter the gas flows to the reactor inlet manifold.

Three dryers are provided for each gas system; two are normally in service while the third dryer serves as a maintenance spare. In the dual reactor areas, B and C and D and DR, the third dryer is shared by the two gas systems. Of the two dryers in service, one dryer is on drying service in the recirculation loop while the other is being regenerated. During regeneration the blower forces gas through a heat exchanger which heats the gas to remove the moisture from the

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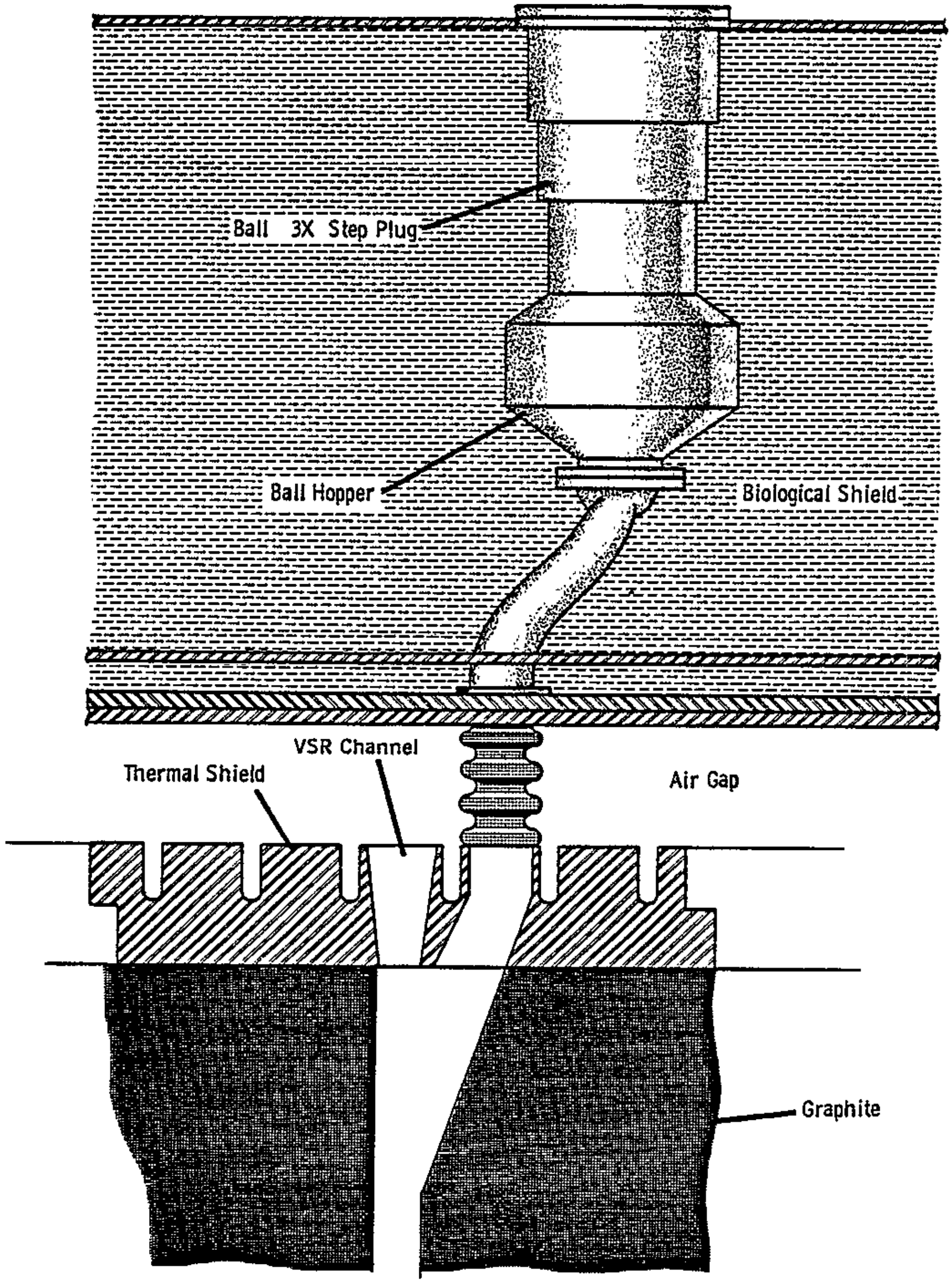

FIGURE VII-9

Ball 3-X Safety System,
C Reactor

Ball 3X Backup Safety System has been installed at each reactor. The system requires no supplementary power supply and operates by gravity. The system utilizes both 3/8-inch and 7/16-inch diameter nickle plated boron steel, nickle plated carbon steel, and stainless steel balls which drop into the vertical safety rod channels upon trip of the Ball 3X circuit.

1. B, D and F Reactors

The Ball 3X systems at these three reactors are identical as shown in Figure VII-8. There are twenty-nine hoppers, each of which contains 925 pounds of mixed nickle plated boron steel and carbon steel balls, all 3/8-inch diameter.

The system is tripped manually from the reactor control room, or automatically upon rapid loss of cooling water pressure. Details of the 3X Safety Circuit are given in Section VIII - Reactor Instrumentation. Tripping of the 3X circuit causes rapid discharge of the hopper contents into connected VSR channels. The first balls reach the bottom of the channel approximately two and one-half seconds after a trip signal is initiated, and the channels are filled within 16 seconds.

Ball removal is accomplished by use of a vacuum system which, through the use of long tubes, lifts the balls from the bottom of the individual channels.

2. DR and H Reactors

The operation of the Ball 3X system in the DR and H Reactors is identical to the B, D and F Reactors as shown in Figure VII-8. However, slightly larger vertical openings were provided to further reduce the possibility of obstructed channels. These channels have a cross-section 4-3/16 inches square. The DR Reactor has twenty-nine ball hoppers and the H Reactor has forty-five. The weight of a full hopper of balls at each reactor is 1200 pounds. At DR Reactor, there has been enough stack separation and graphite breakage so that some balls have been retained in the stack structure after a spurious ball-drop.

3. C Reactor

The C Reactor has forty-five ball hoppers, each containing 1450 pounds of balls. The vertical channel is 4-3/16 inches square and is shown in Figure VII-9. Ball removal was simplified at C Reactor by the installation of valves on the face of the bottom biological shield. These valves are connected to the channel in the graphite by a pipe running through the bottom thermal and biological shield. The pipe is curved to provide shielding and the volume of balls in the hopper was increased to account for the volume of the pipe. Filling a VSR channel with balls takes slightly longer at C Reactor because of the time required to fill this pipe.

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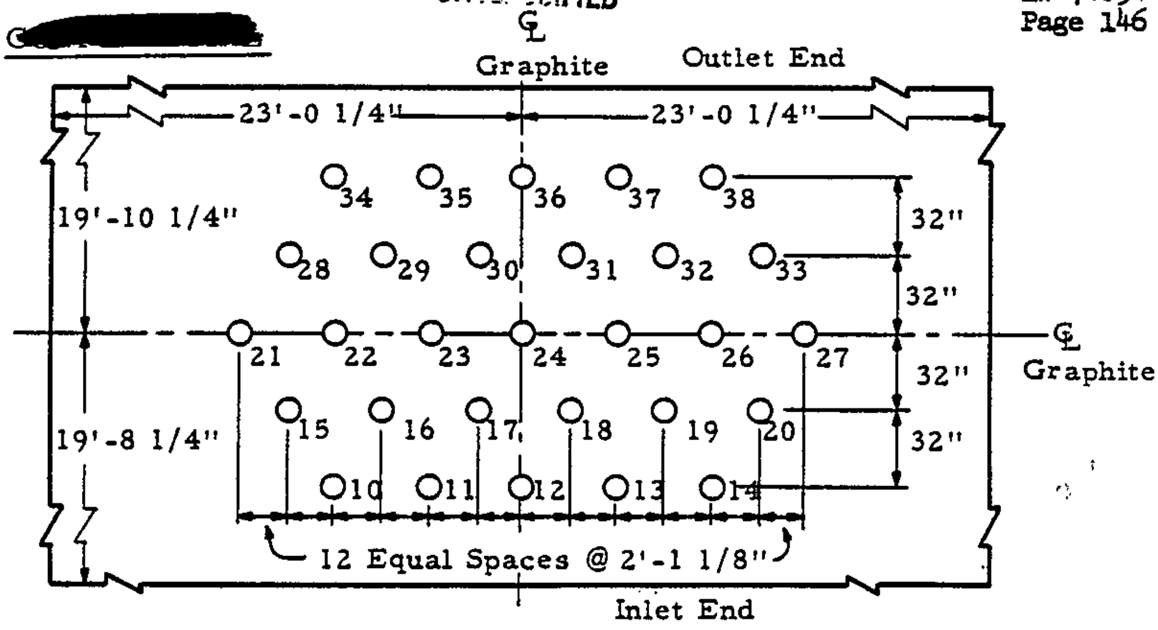
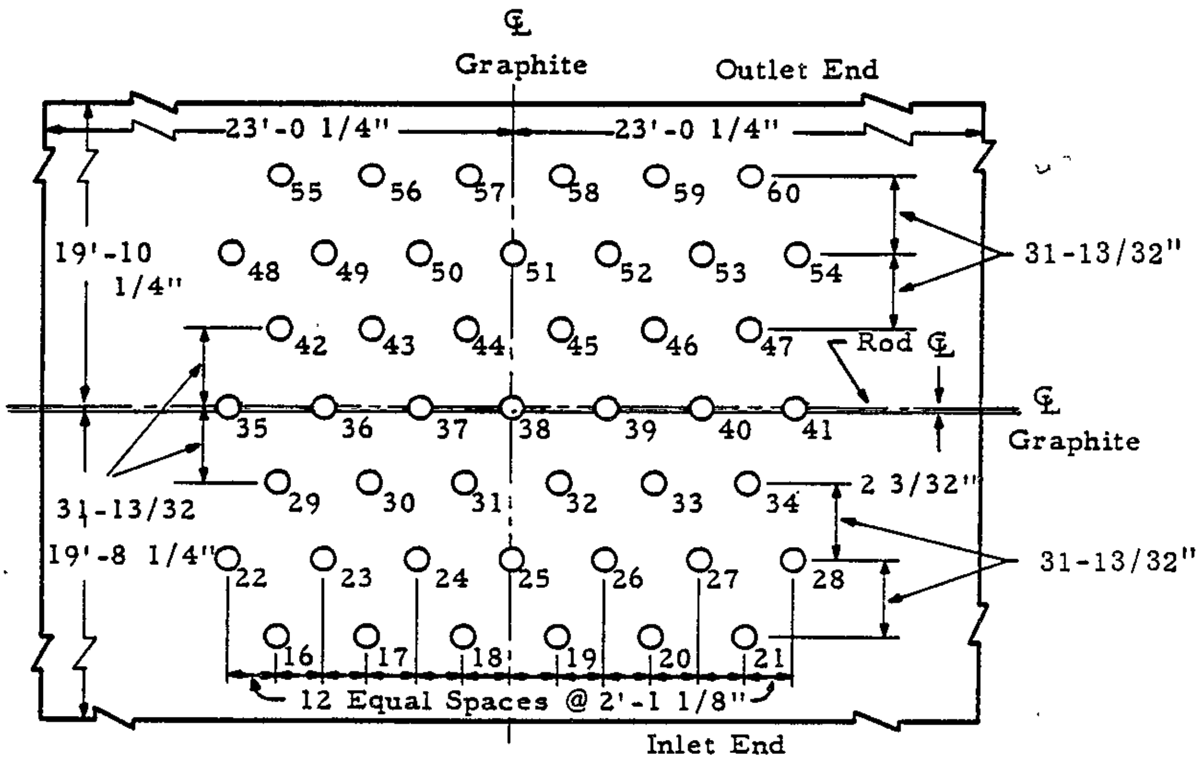


B, D, F, & DR VSR SYSTEM



C & H VSR SYSTEM

FIGURE VII-7

Vertical Safety Rod System Layout

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VI. REACTOR COOLING

A. Reactor Inlet Piping

1. General

The original reactor inlet process piping at the B, D, DR, F, and H Reactors has been modified to provide for increased cooling water flow, higher pressures and improved hydraulic efficiency. Essentially new piping systems were installed from the 105 Building Valve Pit to the front face crossheaders at the B, D, DR, and F Reactors. At the H Reactor, the pipe replacement was not as extensive and much of the original is still in use. At the C Reactor, no inlet cooling water piping changes were made.

The inlet piping of all reactors from the valve pit to the crossheader tube fittings is designed for a minimum non-shock, cold water, working pressure of 600 psi. In addition, the piping systems from the 190 Building cooling water pumps to the crossheaders were hydrostatically tested at 1-1/2 times the working pressure, or 900 psi.

The basic design of the inlet water piping systems of all reactors are alike. The pipe carries the water from the 190 Building cooling water pumps to the reactor front face and distributes it to the individual process tubes. There are, however, notable differences in the piping systems of the different reactors in arrangement, size, material, and pressure ratings of the pipe and valves. Because of the importance of the cooling water piping system to safe reactor operation, each system is described separately. In addition, the size, material, and pressure rating of each component in the reactor cooling water system, from the 105 Building Valve Pit to the inlet nozzles, is noted for each reactor in Figures VI-1, VI-2, VI-3, and VI-4.

2. B, D, and F Reactors

Cooling water pipe from the common crossheader in the 105 Building Valve Pit is divided into two 36-inch headers which run to the base of the reactor. Venturi tubes, which measure the water flow rate, are located in this straight pipe run. The high tank emergency water system ties into these headers downstream of the venturi tubes. The emergency system is isolated from the primary and secondary water systems by check valves.

At the base of the reactor, the water flow is directed upward through base ells to the 36-inch risers on both sides of the reactor face. The base ells are 36-inch, 90-degree, mitered elbows which have structural bases for supporting the risers. The water is then distributed across the reactor front face through 4-inch, Schedule 40, stainless steel crossheaders, which are connected to the risers at both ends. The riser-crossheader connection is made up of a 5-inch, Schedule 80, carbon steel, expansion loop; a 5-inch, carbon steel, 400# check valve; an insulating flange, a 5-inch, stainless steel, 400# strainer with an 8 x 8 mesh screen; a 4 x 5-inch stainless steel reducer; and a 4-inch, stainless steel, 300# gate valve.

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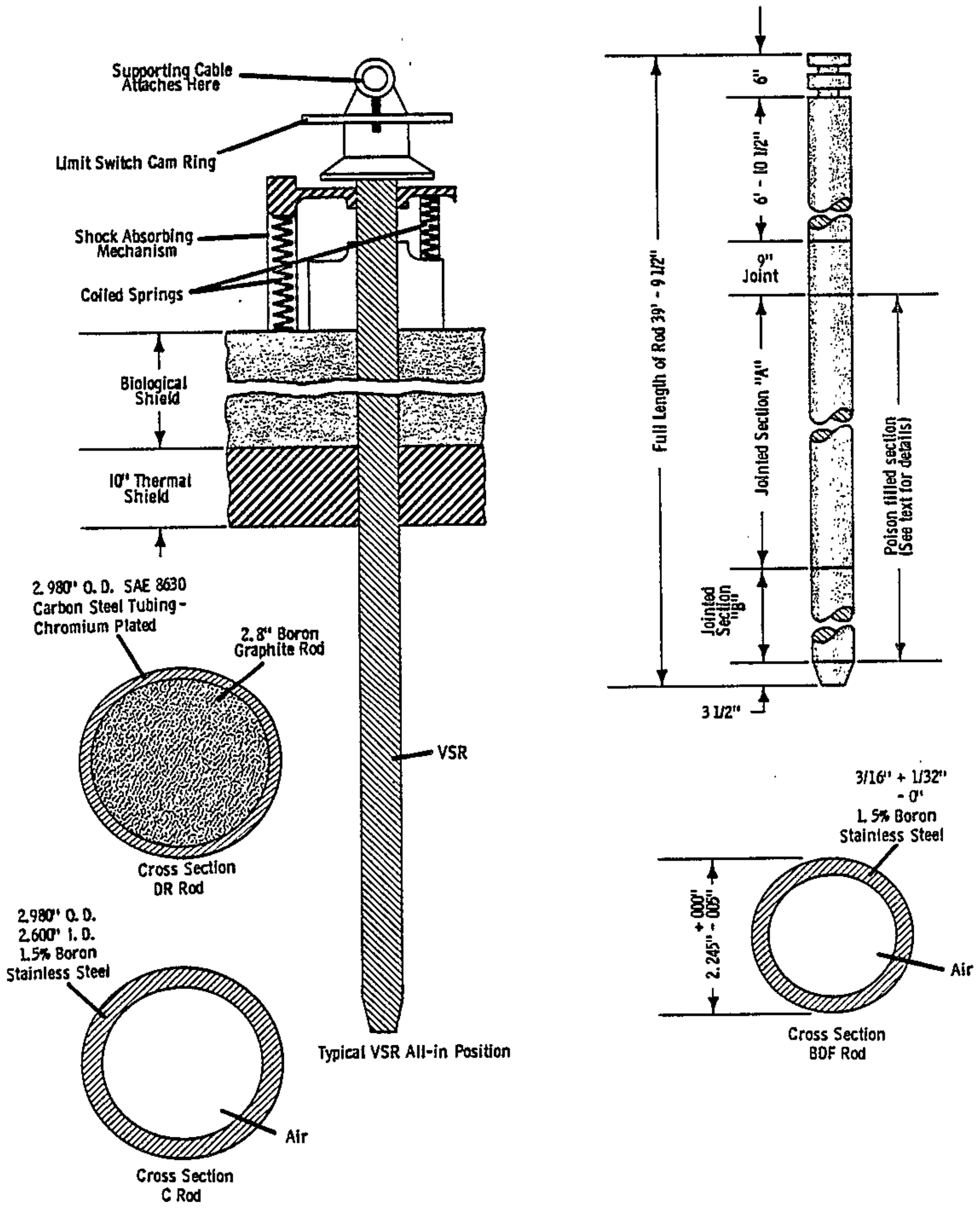

FIGURE VII-6

Vertical Safety Rod Structural Details

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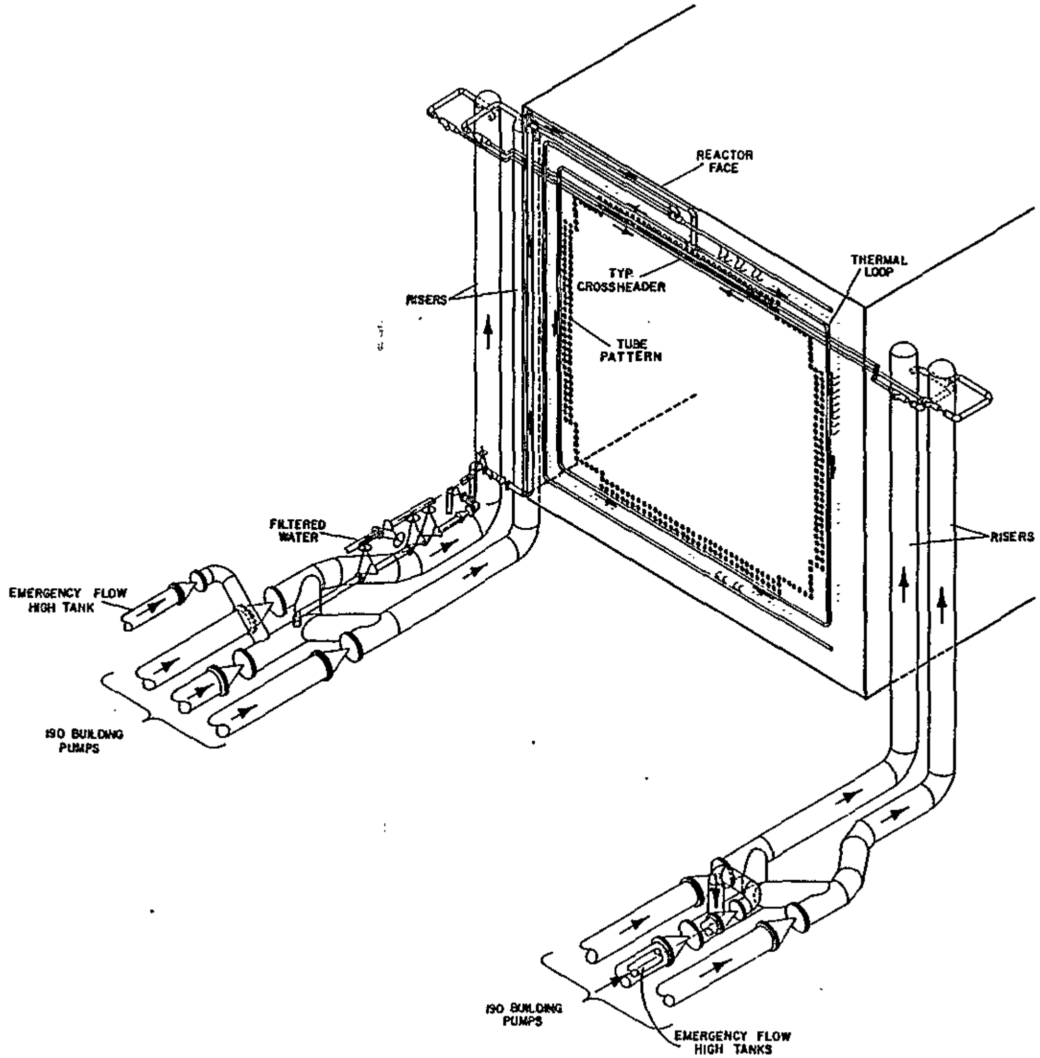


FIGURE VI-2

Valve Pit to Inlet Nozzle Piping, C Reactor

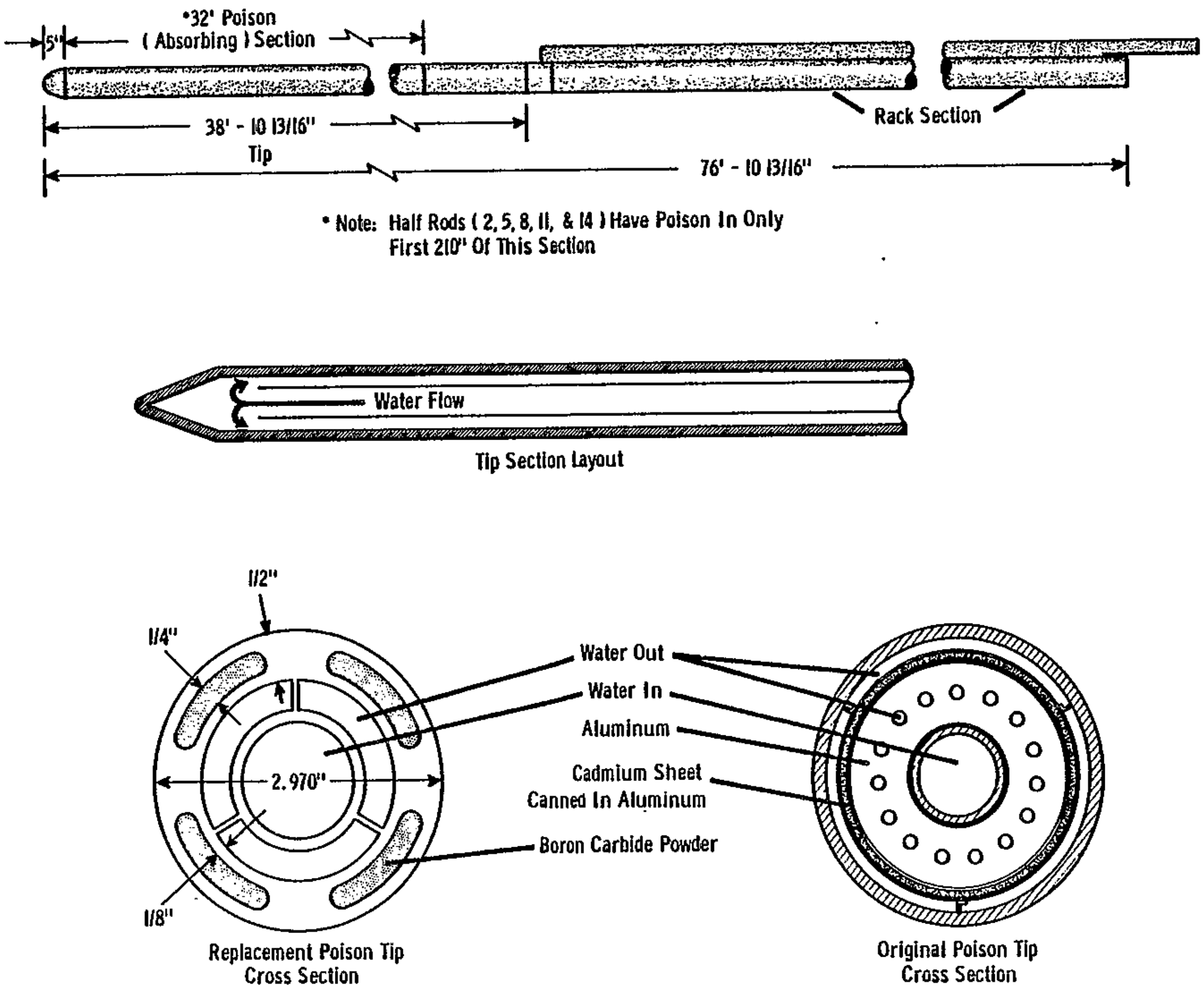


FIGURE VII-4

Horizontal Control Rod Assembly, C Reactor

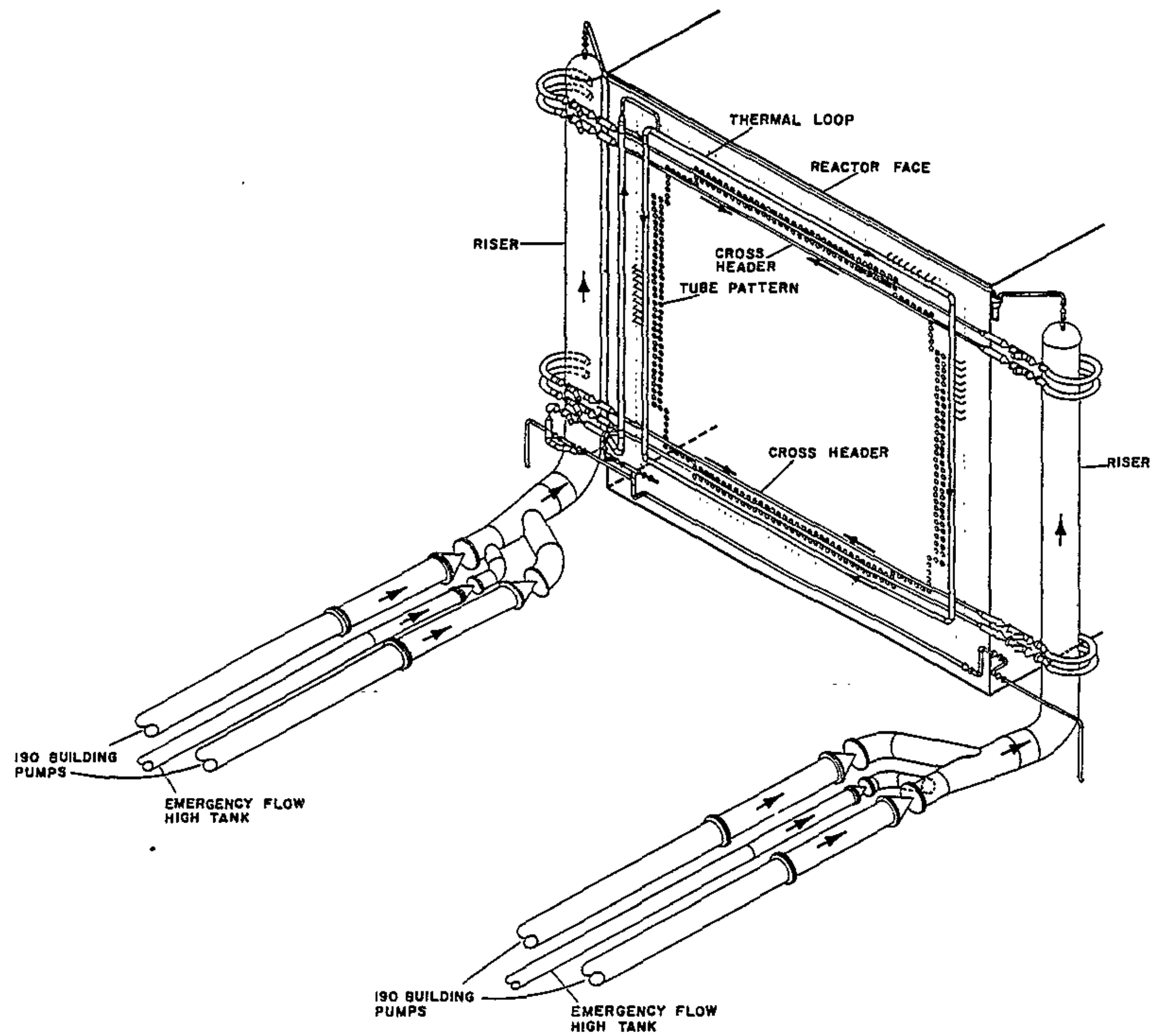
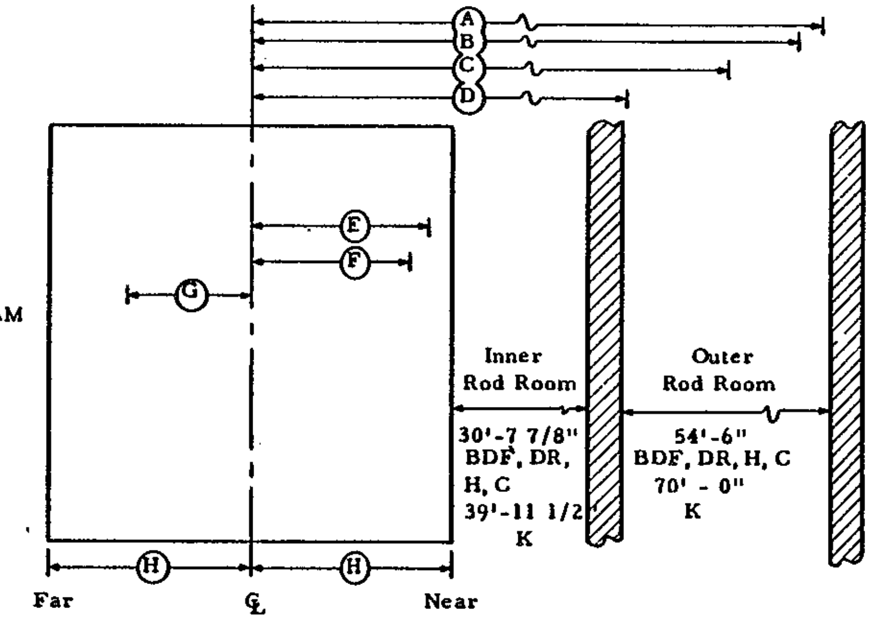


FIGURE VI-4

Valve Pit to Inlet Nozzle Coolant Piping,
H Reactor

HCR
OPERATING DIAGRAM



KEY									
Dim.	Code	B	C	D	DR	F	H	KE	KW
A	Rod Full-out Position	95'-5 5/8"	98'-4 11/16"		95'-5 5/8"		95'-5 5/8"	112'-6 7/8"	
B	Rod Normal-out Position	93'-5 1/32"	95'-5 15/16"		93'-5 1/32"		93'-3 3/8"	108'-5 1/2"	
C	Rod Full-in Position	64'-7 1/32"	65'-3 15/16"		64'-2 27/32"		63'-3 3/8"	74'-1 7/8"	
D	Pile ℄ to Outer Rod Rm.	56'-0 1/8"	56'	Same as B	56'-0 1/8"	Same as B	56'	70'-0 1/2"	Same as KE
E	Rod-Tip Full-out Position	20'-0 1/4"	20'-8 3/4"		20'-0 1/4"		20'-8 3/4"	24'-7"	
F	Rod-Tip Normal-out Position	17'-1121/32"	17'-10"		17'-9 21/32"		17'-10"	20'-5 5/8"	
G	Rod-Tip Full-in Position	10'-10-11/32"	14'-0"		11'-2 17/32"		12'-2"	17"-11 3/8"	
H	Pile ℄ to Outside of "B" Shield	23'-0 1/4"	23'-0 1/4"		23'-0 1/4"		23'-0 1/4"	27'-1"	
	Total Rod Length	75'-5 3/8"	77'-7 15/16"		75'-5 3/8"		75'-5 3/8"	92'-1 1/4"	

FIGURE VII-3

Horizontal Control Rods, Operating Diagram

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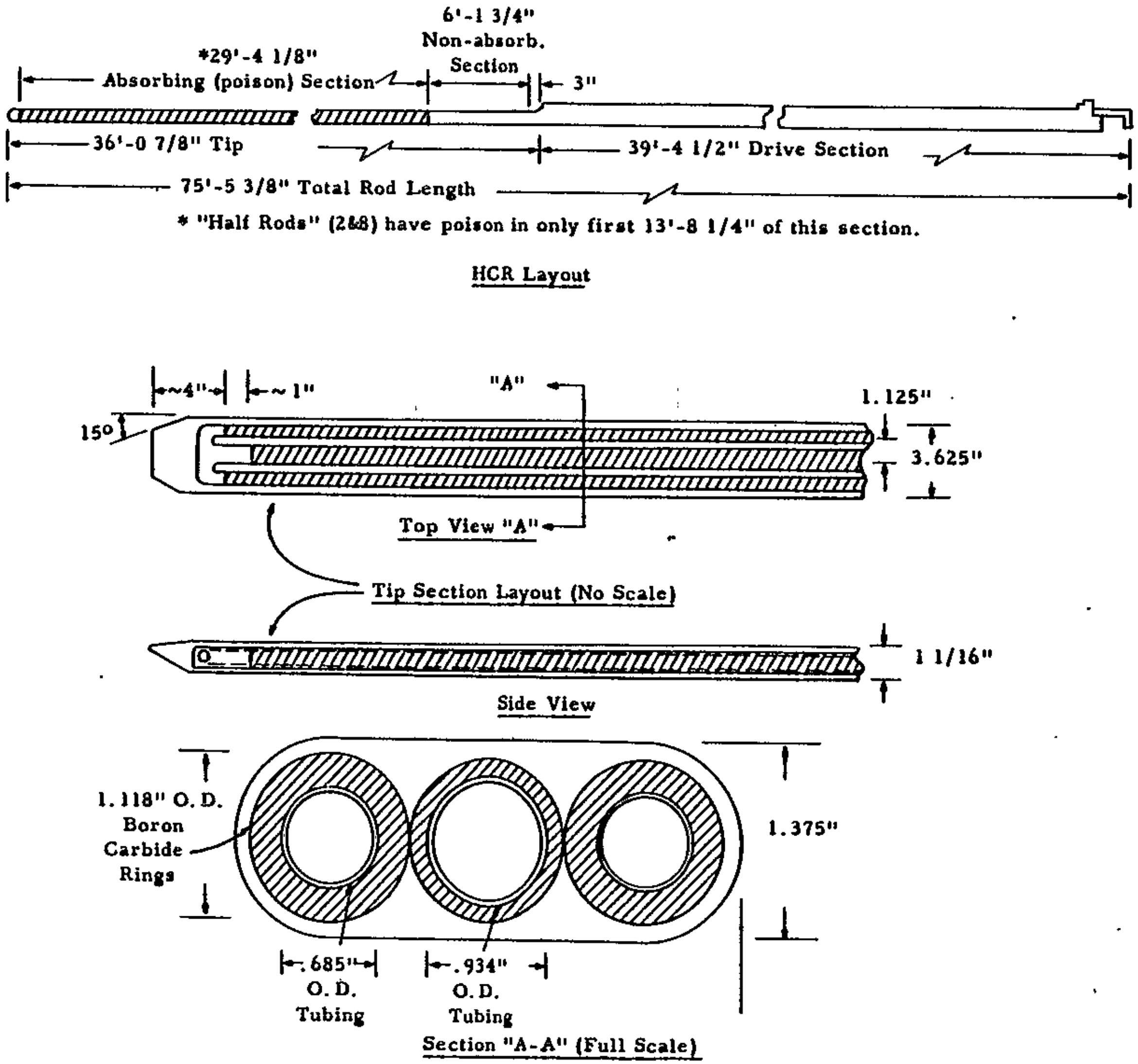

FIGURE VII-2

Horizontal Control Rods, B, D, DR, F, and H Reactors

C. Miscellaneous Systems

Three additional water systems, which are common to all of the reactors: the single-tube high-pressure water system; the solids feed system; and the hot water circulating system.

1. Single-Tube High-Pressure System

The single-tube high-pressure system is used for discharging poison column control tubes during operation and for flush discharging single process tubes. The system is made up of a 1-1/2- or 2-inch, Schedule 40, riser located on the side of the reactor front face, with valved outlets spaced approximately every six feet. The front face work platform has a 1-1/2- or 2-inch header, with valved outlets spaced approximately every five feet. To supply water to a single tube, the platform is positioned, the riser is connected to the header on the platform with a flexible hose, and in turn, the header is connected to the tube with a flexible hose. The system is supplied either by the reactor cooling water system or the high-pressure solids feed pump, depending upon the pressure desired.

2. Solids Feed System

The solids feed system injects a slurry of diatomaceous earth into the reactor cooling water to scour the corrosion film from the inner surfaces of the piping, the process tube, and fuel elements in order to reduce friction losses in the system. The diatomaceous earth slurry make-up tanks and the two high-pressure injection pumps, rated at 200 gpm at 700 psi, are located in the 105 Building Valve Pit at the B, D, DR, and F Reactors and in the 190 Building at the C and H Reactors. The point of injection is in the cooling water headers in the valve pit in the 105 Building. The capacity of the system is approximately 400 gpm, permitting a solids concentration in the reactor cooling water during a "purge" of from 25 to 50 ppm.

3. Hot Water Circulating System

A hot water circulating system is provided for drying out the graphite moderator during a period of reactor shutdown when the stack contains too much water to permit drying during reactor operation. The system recirculates hot water (150 - 200 F) through the process tubes, thereby heating the graphite and causing the water to vaporize and be removed with the circulating gas atmosphere system. The hot water is injected in the front risers, circulated through the reactor, and returned through the circulating pumps in the valve pit. The capacity of the system is 2000 gpm at the B, D, DR, and F Reactors and 1000 gpm at the C and H Reactors.

Heating for the hot water system is supplied from the 225 psi steam loop in 105 Building.

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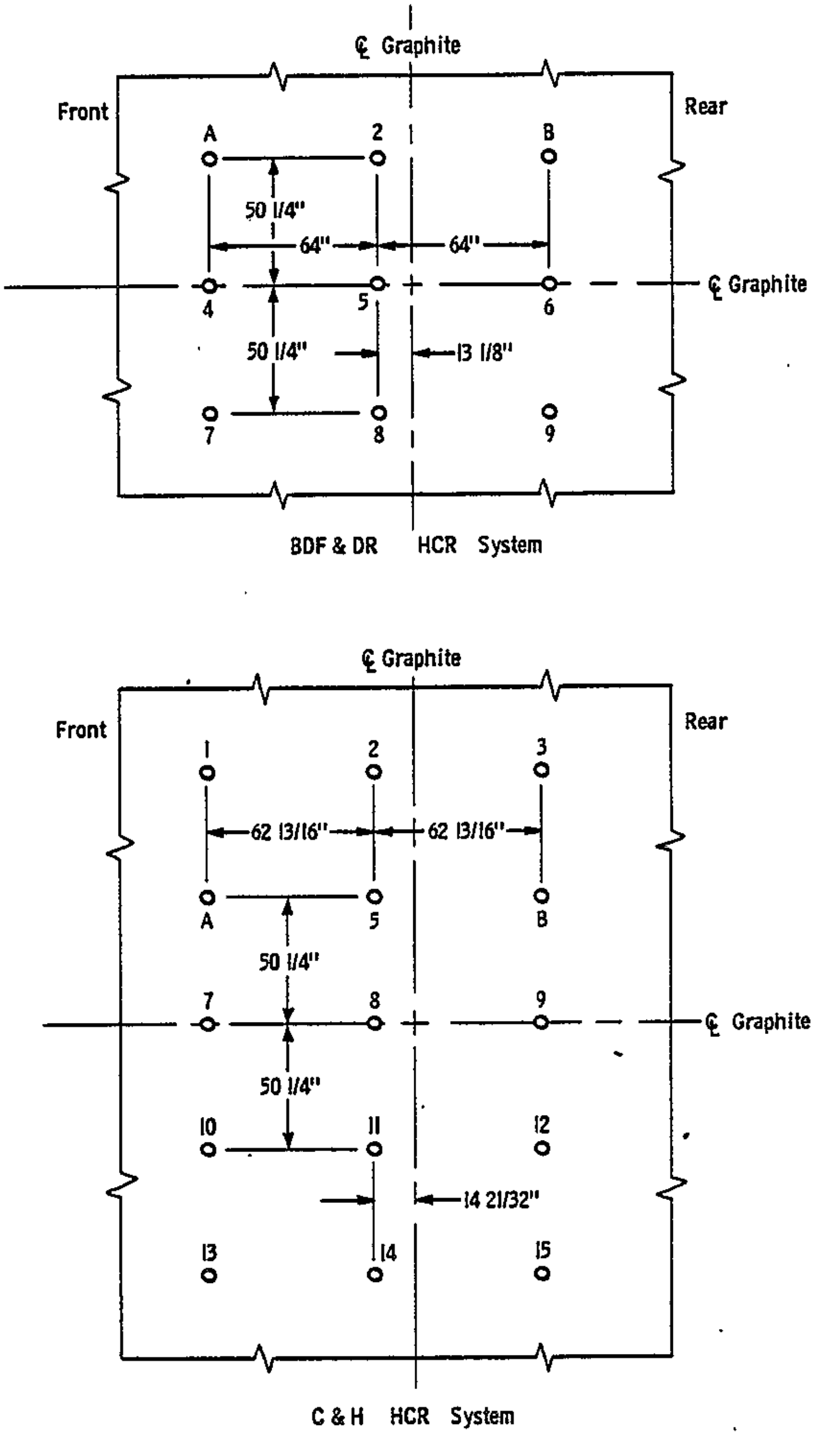

FIGURE VII-1
Horizontal Control Rod Arrangement

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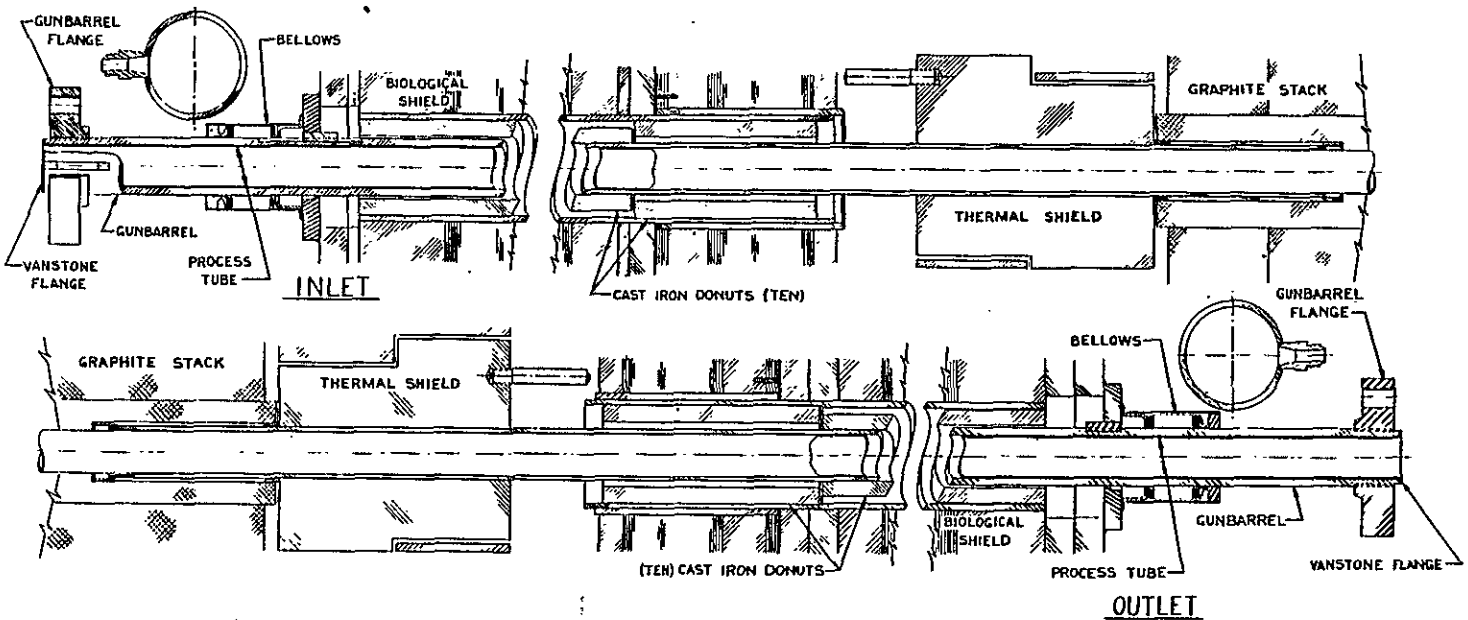

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FIGURE VI-5

Process Tube Channel Cross Section

5. F Reactor

The F Reactor effluent system, shown in Figure VI-16, consists of one 60-inch carbon steel pipe line from the downcomer to the intake of the 107-F Retention Basin. From the outlet of the retention basin, the effluent system consists of one 60-inch by 1/2-inch thick wall, carbon steel pipe line which runs to the outfall structure. The outfall discharge to the center of the river is two 42-inch reinforced concrete pipe lines.

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In addition to the standard size aluminum and Zircaloy-2 tubes in the reactors, there are sixty-one Zircaloy-2 overbore type tubes installed in the C Reactor. These tubes were installed under a development program to demonstrate the technique of enlarging process tube channels to permit installing larger diameter process tubes for irradiating larger diameter fuel elements. In this program, the standard size gunbarrel and the cast iron donuts, except the donut at the inner surface of the biological shield, were removed from the process channels. The single donut and the thermal shield penetrations were enlarged (overbored) to fit larger gunbarrels. The graphite channels were then enlarged 550 mils to permit installation of 2.225-inch maximum O.D. Zircaloy-2 tubes with a 40 mil minimum wall thickness. Of these sixty-one enlarged channels, forty-eight are grouped in a square block in the central zone of the reactor. This block of channels is being used to experimentally determine the performance and conversion ratio of the fuel and other physics data in the higher uranium to graphite ratio tube lattices resulting from the overboring.

3. Nozzle Assembly

The standard inlet nozzle assembly for the B, D, DR, F, and H Reactors, as shown on Figure VI-7, was installed during the modification program of 1956. The nozzle assembly is bolted directly to the gunbarrel flange to effect the water seal between the process tube and nozzle. The end of the nozzle has a removable cap provided for charging fuel elements into the process tube. Attached to the cap is solid aluminum plug which serves as shielding against the gamma beams emanating from the fuel elements in the process tube. The water connection from the crossheader to the nozzle is made through a flexible connector and flow monitor assembly. These nozzles are aluminum castings which were radiographed and subjected to a 900 psi hydrostatic test after fabrication.

A nozzle modification program, or the B, D, DR, F and H Reactors will allow the use of a bumper fuel element. Grooves are broached in either side of the nozzle barrel to position the fuel element. Dye penetrant and hydrostatic testing at 900 psig follows. If the nozzle cannot satisfy these requirements, a replacement nozzle made of 6061 T6 aluminum alloy by an impact-extrusion process is substituted.

The standard inlet nozzle assembly of C Reactor is shown on Figure VI-8. This assembly is similar to the B, D, DR, F, and H Reactor assembly except that the flow monitor is located in the nozzle and the connector is 5/8-inch O.D. helically formed Inconel tubing. Dye penetrant, radiograph and hydrostatic tests were performed on these nozzles prior to installation.

In addition to standard inlet nozzles at C Reactor, there are three types of overbore (large) nozzles installed on the overbore tubes. Two of these, the "clamp" and "flapper valve" nozzles, are shown in Figure VI-9. New features of these two nozzle assemblies are: a neoprene bellows gas seal which can be replaced without removing the gunbarrel; a flow monitor with a

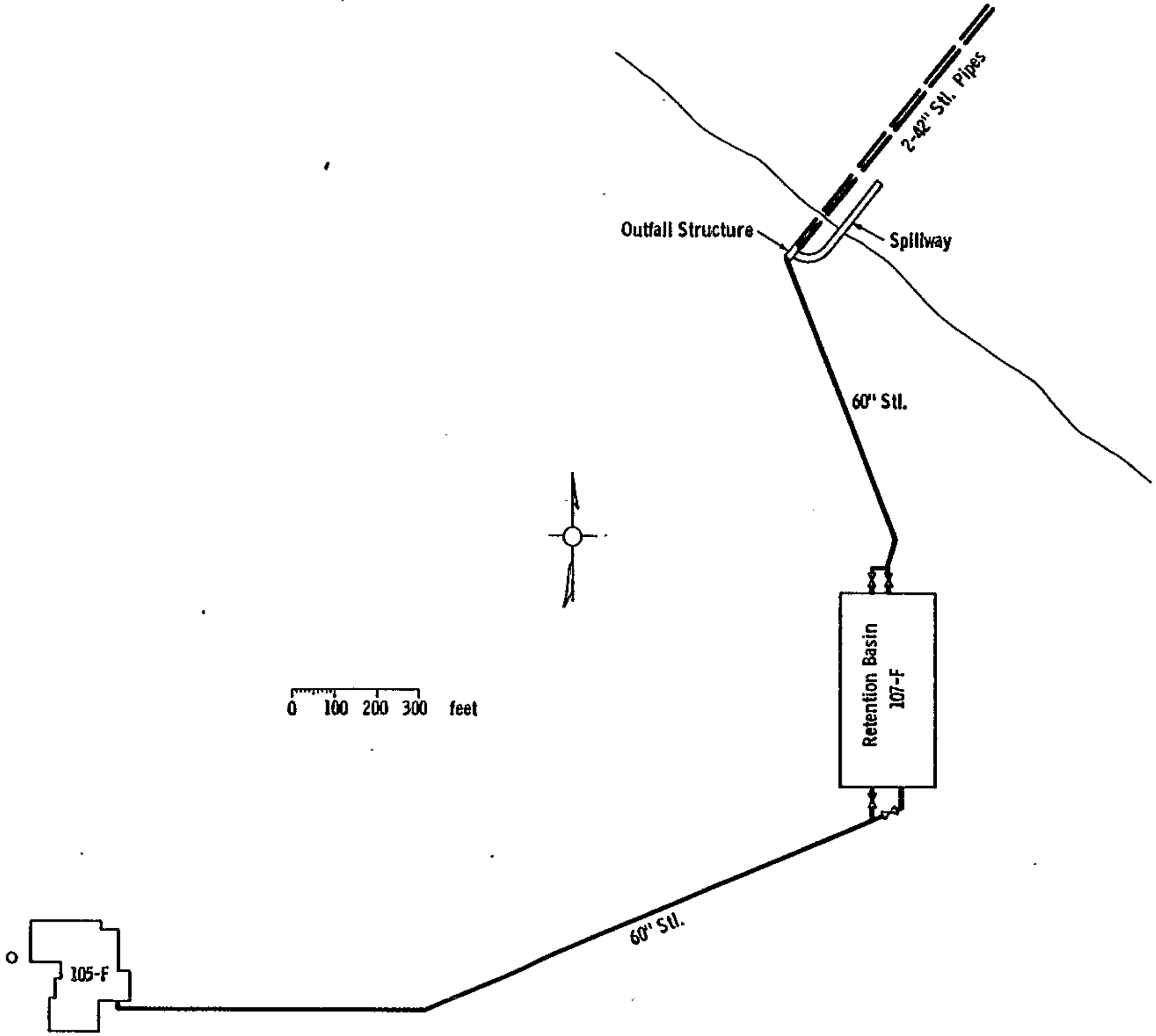

FIGURE VI-15
Effluent System, F Reactor

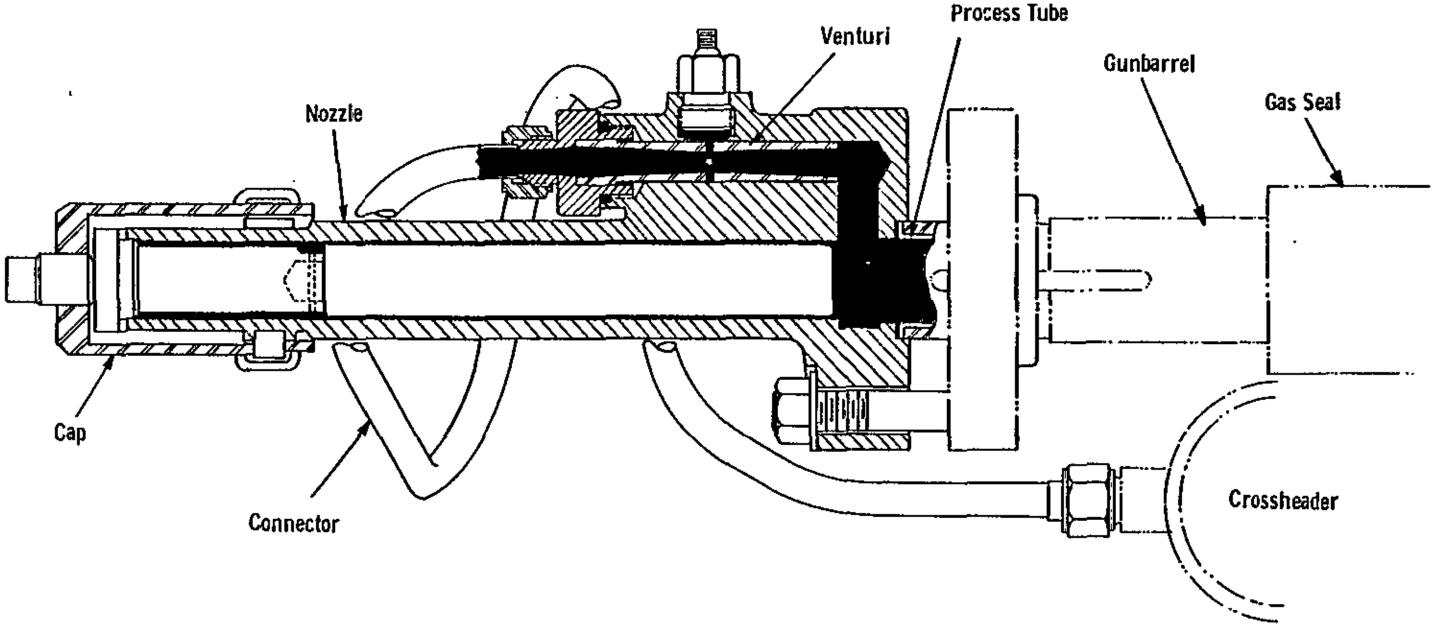

FIGURE VI -8
Inlet Nozzle Assembly, C Reactor

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through a 66-inch pipe line. Immediately downstream of the 107-C west basin, the flow is diverted back to the discharge line from the 107-B Basin. The diversion boxes at these locations are reinforced concrete boxes with electric motor-operated sluice gates.

The construction of the B Reactor effluent pipe line is similar to that of the C Reactor's effluent line. The pipe lengths are connected by Dresser couplings with concrete anchors provided at each change in direction in the pipe line. Expansion boxes are also installed to accommodate thermal fluctuations.

3. D and DR Reactors

The DR Reactor effluent piping at the bottom of the downcomers is made up of two 60-inch by 1/2-inch thich wall, carbon steel pipe lines, shown schematically in Figure VI-14. These lines run parallel to the 107-DR concrete retention basin. Opposite the 105-D Building, the west DR effluent line is cross-tied to the D Reactor 66-inch effluent line by a 60-inch by 1/2-inch thick wall, carbon steel pipe.

The description and operation of the 107-D and DR Retention Basins is similar to the 107-B Retension Basin. At the outlet of the basin the effluent system consists of two 60-inch carbon steel lines, one from each side of the basin. These lines are combined in a junction box to form a single 60-inch line which runs to the outfall structure. The outfall discharge line is a 66-inch carbon steel line which continues to the center of the river.

The D Reactor effluent system at the downcomer is a 66-inch carbon steel line which runs approximately halfway to the retention basin where the line reduces to 60-inch carbon steel pipe and continues to the intake of the 107-D Retention Basin. At the outlet of the retention basin, the effluent line is a 60-inch carbon steel pipe which runs to the outfall structure. The discharge lines from the outfall structure to the center of the river are two 42-inch reinforced concrete pipes.

4. H Reactor

The H Reactor effluent system from the downcomers to the 107-H concrete retention basin consists of two 60-inch carbon steel pipe lines, shown schematically in Figure VI-15. These lines tie into the retention basin intake at the point where motor-operated sluice gates route the water to either section of the basin. The H Reactor Retention Basin is larger than the B, D, DR, and F Retention Basins, being approximately 600 feet long by 270 feet wide and 15 feet deep. A pumping station located in a separate structure can transport the effluent from the 107-H Retention Basin to the emergency crib.

At the outlet of the retention basin, the effluent system consists of two 60-inch carbon steel pipe lines. These lines run to the outfall structure where the discharge piping from the outfall to the center of the river is two 60-inch carbon steel lines.

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replaceable plug for changing the flow range of the tube pressure monitor without installing an entirely new flow monitor; and a flapper valve, installed in the nozzle barrel, which closes to back flow if the nozzle cap is inadvertently blown off during operation.

The strength of these overbore nozzles is considerably in excess of that of the more standard nozzles.

The distribution of water from the crossheaders to the individual tubes is regulated by different size venturis or orifices in the inlet connector.

Flow in each process tube is monitored. Water pressure at the venturi throat, or <u>vena contracta</u> of an orifice, of each tube is connected to a bourdon tube pressure gage, Panellit gage, in the control room, Figure VI-10. Prior to reactor start-up the Panellit gages are individually adjusted for the amount of flow variation allowable for the different tubes. An over or underpressure, out of the acceptable range, activates a safety circuit relay to scram the reactor.

Water from the process tube flows through the nozzle and connector into the rear crossheaders. A thermocouple is installed in each rear nozzle to measure the outlet water temperature of each tube.

The outlet nozzle assembly is similar to the inlet nozzle but has not been standardized for all reactors. There are original nozzles, replacement nozzles, and modified inlet nozzles in service. Before installation, each nozzle assembly is hydrostatically tested at 700 psi.

E. <u>Reactor Outlet Piping</u>

The outlet cooling water piping arrangement on the rear face of the reactors is essentially a duplicate of the inlet piping arrangement. Water from the process tubes flows from the rear nozzle, through the rear hydraulic connector and into the horizontal crossheaders. The crossheaders join two vertical risers, one on each side of the reactor face. On one side the water flows upward in the riser and through a crossover line where it is joined by the water from the other riser, the total flow is then downward into the cascade type downcomer. From the downcomer outlet the water flows, by gravity, through the effluent system piping to retention basins, subsequently to be discharged underwater in the center of the river. The rear crossheaders are 4-inch, Schedule 40, stainless steel pipe with 4-inch, 150#, gate valves attached at each end. Nozzle connector fittings on the crossheaders are welded 5/8-inch male stainless steel tube fittings at the B, D, DR, F, and H Reactors and 1-inch fittings at the C Reactor. The crossheaders are flanged to 4-inch, Schedule 40, stainless steel pipe expansion loops welded to the riser walls.

The risers are 36-inch diameter pipes with 3/16-inch wall at the B, D, DR, F, and H Reactors and 1/4-inch wall at the C Reactor. The risers are stainless steel at the B, D, and F Reactors and carbon steel with a 20% thick stainless steel cladding at the DR, H, and C Reactors. The risers

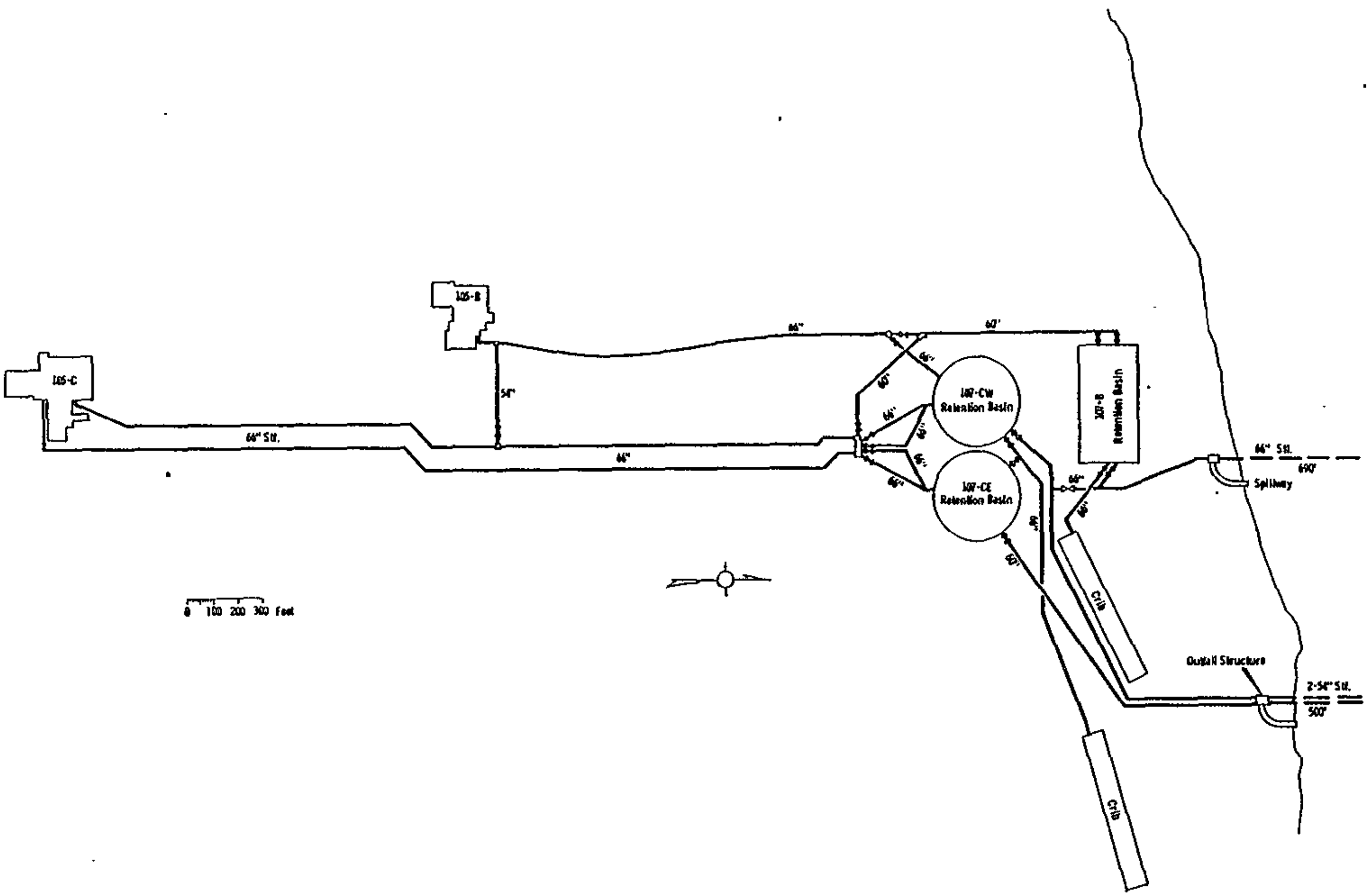

FIGURE VI -13
Effluent System, B and C Reactors

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tie into the crossover line which is located on the face of the reactor above the process tube pattern and extends across the reactor face. The crossover line is of the same diameter and material as the risers. The crossover line increases in size to a 42-inch diameter pipe at the downcomer approach at the B, D, DR, F, and H Reactors and to 54-inches at the C Reactor. The downcomer, located on the side of the reactor face, is a rectangular vessel encased in concrete, approximately 72-inches by 120-inches by 55-feet long with perforated trays spaced at approximately six-foot intervals. The downcomer serves to dissipate the energy of the falling effluent water by cascading over the trays. The downcomer is vented to remove the air and steam released from the water which is vented into the building ventilation system for release from the exhaust stack.

There is one downcomer at the B, D, and F Reactors and two at the DR, H, and C Reactors. The piping systems with dual downcomers have motorized gate valves in the crossover lines at the downcomer approach. All reactors operate with one downcomer in service. Change over to another downcomer is made only when the reactor is shutdown.

There is another drain system in the outlet process piping system called the crossunder line. This line is a 20-inch, Schedule 10, carbon steel pipe line with a motorized gate valve, and is connected directly to the bottom of a rear riser and discharges into the effluent system. At the B, C, D, and H Reactors, the tie-in is to the near riser and the base of the downcomer. At the DR Reactor, the tie-in is to the far riser and downcomer. At the F Reactor, the crossunder line ties into the near riser and discharges into the 1608 Building sewer lift station where the water is pumped into the effluent system.

The function of the crossunder system is to remove the static water pressure in the crossheaders during shutdown when the reactor flow is reduced. The crossheaders at the opposite riser are valved off and all water flow is directed to the riser having the crossunder line. The water is then discharged directly to the effluent system with no static head in the risers. If it is desired to further reduce flow in a single crossheader or group of crossheaders the particular front crossheaders are valved off at the near riser and flow is reduced with the crossheader valves at the far riser until a certain pressure differential between the front and rear crossheaders on the near side is obtained.

The reactor outlet process piping is rated for a working pressure of 150 psi. Cyclic thermal expansion in the system is relieved by expansion joints in the crossover line and downcomer approaches and by expansion loops for the crossheaders. The crossheaders were initially installed with approximately 1/8-inch cold spring which has helped to relieve the thermal stresses in the system.

Figures VI-11 and VI-12 show typical reactor outlet piping arrangements with one downcomer and two downcomers, respectively.

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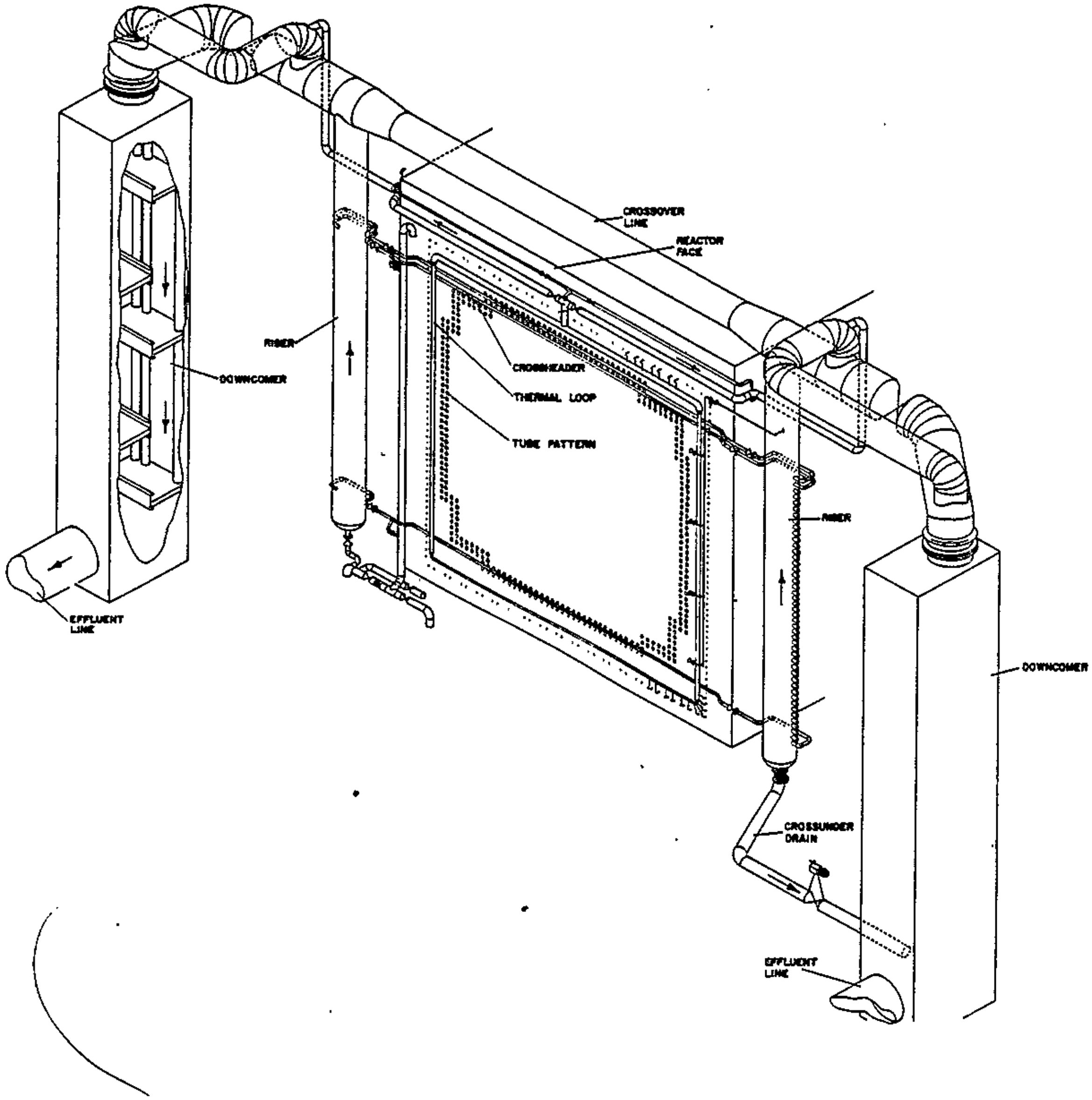

FIGURE VI-12

Typical Reactor Outlet Coolant Piping with Two Downcomers, 105 Building

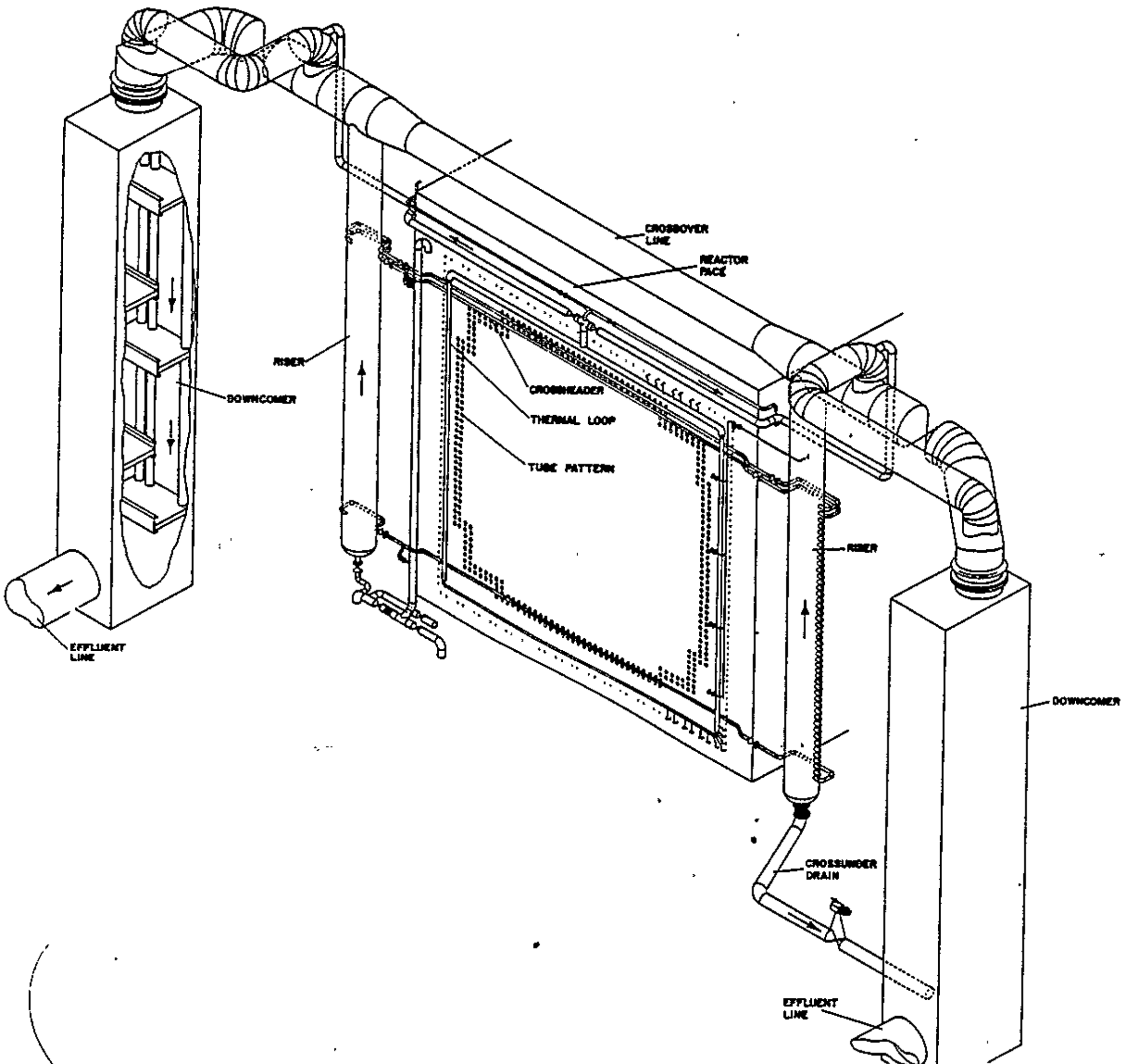

FIGURE VI-12

Typical Reactor Outlet Coolant Piping with Two Downcomers, 105 Building

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tie into the crossover line which is located on the face of the reactor above the process tube pattern and extends across the reactor face. The crossover line is of the same diameter and material as the risers. The crossover line increases in size to a 42-inch diameter pipe at the downcomer approach at the B, D, DR, F, and H Reactors and to 54-inches at the C Reactor. The downcomer, located on the side of the reactor face, is a rectangular vessel encased in concrete, approximately 72-inches by 120-inches by 55-feet long with perforated trays spaced at approximately six-foot intervals. The downcomer serves to dissipate the energy of the falling effluent water by cascading over the trays. The downcomer is vented to remove the air and steam released from the water which is vented into the building ventilation system for release from the exhaust stack.

There is one downcomer at the B, D, and F Reactors and two at the DR, H, and C Reactors. The piping systems with dual downcomers have motorized gate valves in the crossover lines at the downcomer approach. All reactors operate with one downcomer in service. Change over to another downcomer is made only when the reactor is shutdown.

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The reactor outlet process piping is rated for a working pressure of 150 psi. Cyclic thermal expansion in the system is relieved by expansion joints in the crossover line and downcomer approaches and by expansion loops for the crossheaders. The crossheaders were initially installed with approximately 1/8-inch cold spring which has helped to relieve the thermal stresses in the system.

Figures VI-11 and VI-12 show typical reactor outlet piping arrangements with one downcomer and two downcomers, respectively.

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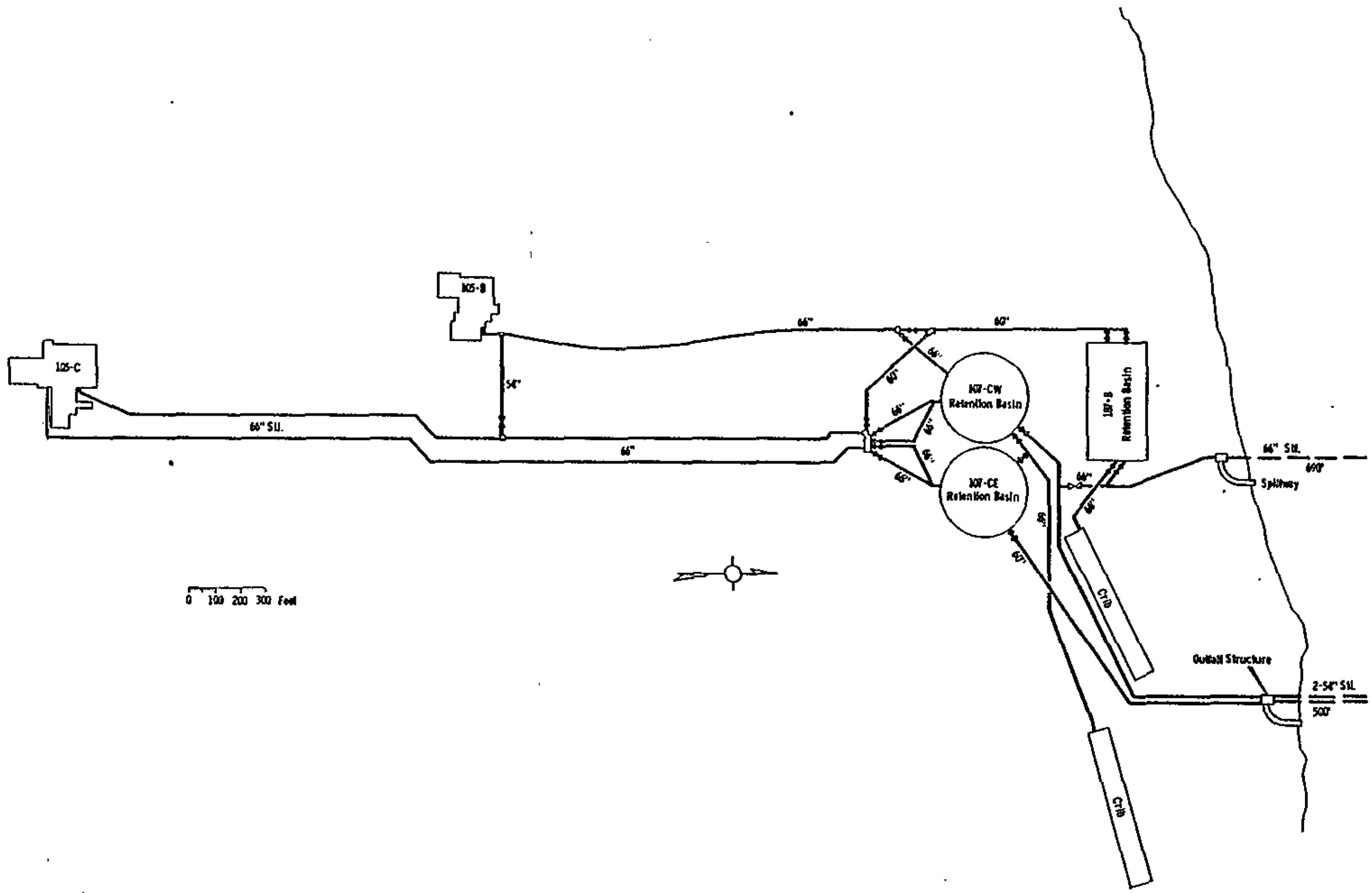

FIGURE VI-13
Effluent System, B and C Reactors

replaceable plug for changing the flow range of the tube pressure monitor without installing an entirely new flow monitor; and a flapper valve, installed in the nozzle barrel, which closes to back flow if the nozzle cap is inadvertently blown off during operation.

The strength of these overbore nozzles is considerably in excess of that of the more standard nozzles.

The distribution of water from the crossheaders to the individual tubes is regulated by different size venturis or orifices in the inlet connector.

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Water from the process tube flows through the nozzle and connector into the rear crossheaders. A thermocouple is installed in each rear nozzle to measure the outlet water temperature of each tube.

The outlet nozzle assembly is similar to the inlet nozzle but has not been standardized for all reactors. There are original nozzles, replacement nozzles, and modified inlet nozzles in service. Before installation, each nozzle assembly is hydrostatically tested at 700 psi.

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The risers are 36-inch diameter pipes with 3/16-inch wall at the B, D, DR, F, and H Reactors and 1/4-inch wall at the C Reactor. The risers are stainless steel at the B, D, and F Reactors and carbon steel with a 20% thick stainless steel cladding at the DR, H, and C Reactors. The risers through a 66-inch pipe line. Immediately downstream of the 107-C west basin, the flow is diverted back to the discharge line from the 107-B Basin. The diversion boxes at these locations are reinforced concrete boxes with electric motor-operated sluice gates.

The construction of the B Reactor effluent pipe line is similar to that of the C Reactor's effluent line. The pipe lengths are connected by Dresser couplings with concrete anchors provided at each change in direction in the pipe line. Expansion boxes are also installed to accommodate thermal fluctuations.

3. D and DR Reactors

The DR Reactor effluent piping at the bottom of the downcomers is made up of two 60-inch by 1/2-inch thich wall, carbon steel pipe lines, shown schematically in Figure VI-14. These lines run parallel to the 107-DR concrete retention basin. Opposite the 105-D Building, the west DR effluent line is cross-tied to the D Reactor 66-inch effluent line by a 60-inch by 1/2-inch thick wall, carbon steel pipe.

The description and operation of the 107-D and DR Retention Basins is similar to the 107-B Retension Basin. At the outlet of the basin the effluent system consists of two 60-inch carbon steel lines, one from each side of the basin. These lines are combined in a junction box to form a single 60-inch line which runs to the outfall structure. The outfall discharge line is a 66-inch carbon steel line which continues to the center of the river.

The D Reactor effluent system at the downcomer is a 66-inch carbon steel line which runs approximately halfway to the retention basin where the line reduces to 60-inch carbon steel pipe and continues to the intake of the 107-D Retention Basin. At the outlet of the retention basin, the effluent line is a 60-inch carbon steel pipe which runs to the outfall structure. The discharge lines from the outfall structure to the center of the river are two 42-inch reinforced concrete pipes.

4. H Reactor

The H Reactor effluent system from the downcomers to the 107-H concrete retention basin consists of two 60-inch carbon steel pipe lines, shown schematically in Figure VI-15. These lines tie into the retention basin intake at the point where motor-operated sluice gates route the water to either section of the basin. The H Reactor Retention Basin is larger than the B, D, DR, and F Retention Basins, being approximately 600 feet long by 270 feet wide and 15 feet deep. A pumping station located in a separate structure can transport the effluent from the 107-H Retention Basin to the emergency crib.

At the outlet of the retention basin, the effluent system consists of two 60-inch carbon steel pipe lines. These lines run to the outfall structure where the discharge piping from the outfall to the center of the river is two 60-inch carbon steel lines.

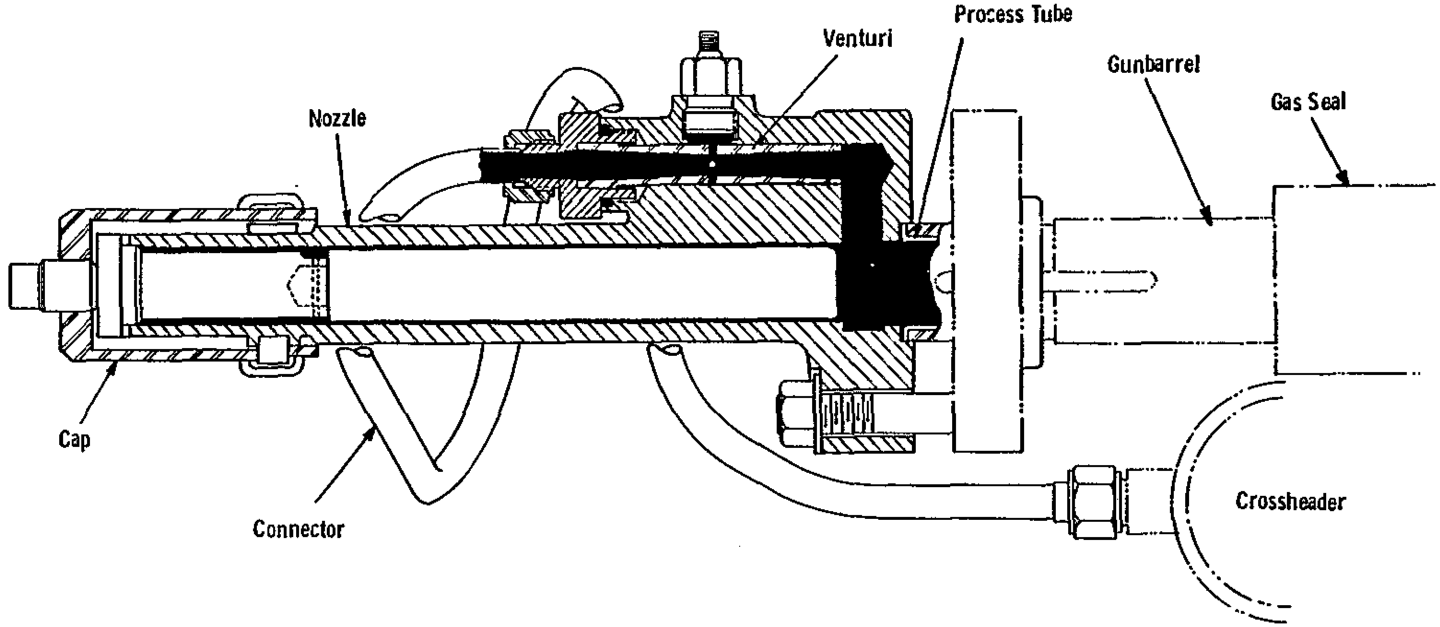

FIGURE VI-8
Inlet Nozzle Assembly, C Reactor

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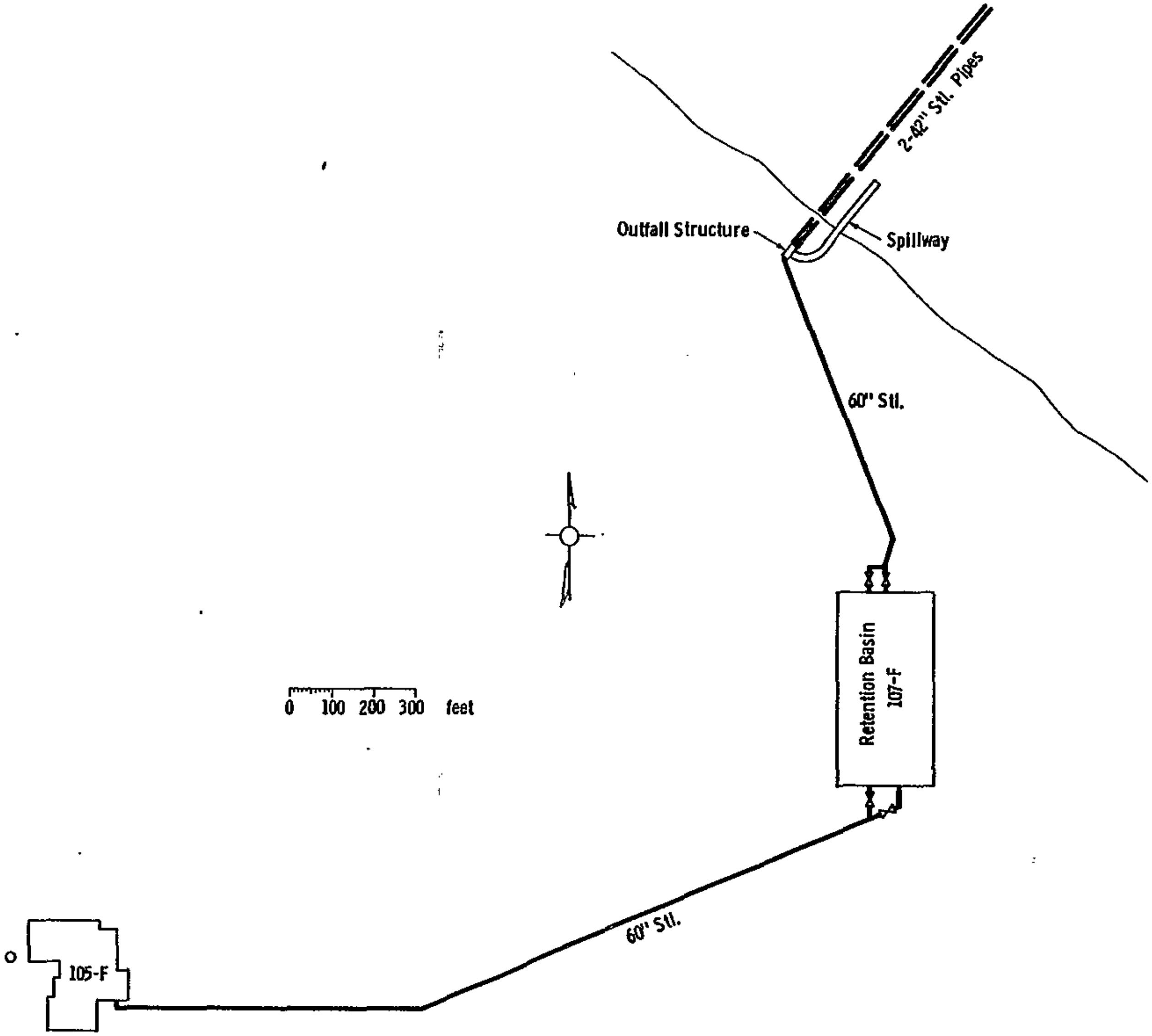

FIGURE VI-15

Effluent System, F Reactor

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In addition to the standard size aluminum and Zircaloy-2 tubes in the reactors, there are sixty-one Zircaloy-2 overbore type tubes installed in the C Reactor. These tubes were installed under a development program to demonstrate the technique of enlarging process tube channels to permit installing larger diameter process tubes for irradiating larger diameter fuel elements. In this program, the standard size gunbarrel and the cast iron donuts, except the donut at the inner surface of the biological shield, were removed from the process channels. The single donut and the thermal shield penetrations were enlarged (overbored) to fit larger gunbarrels. The graphite channels were then enlarged 550 mils to permit installation of 2.225-inch maximum O.D. Zircaloy-2 tubes with a 40 mil minimum wall thickness. Of these sixty-one enlarged channels, forty-eight are grouped in a square block in the central zone of the reactor. This block of channels is being used to experimentally determine the performance and conversion ratio of the fuel and other physics data in the higher uranium to graphite ratio tube lattices resulting from the overboring.

3. Nozzle Assembly

The standard inlet nozzle assembly for the B, D, DR, F, and H Reactors, as shown on Figure VI-7, was installed during the modification program of 1956. The nozzle assembly is bolted directly to the gunbarrel flange to effect the water seal between the process tube and nozzle. The end of the nozzle has a removable cap provided for charging fuel elements into the process tube. Attached to the cap is solid aluminum plug which serves as shielding against the gamma beams emanating from the fuel elements in the process tube. The water connection from the crossheader to the nozzle is made through a flexible connector and flow monitor assembly. These nozzles are aluminum castings which were radiographed and subjected to a 900 psi hydrostatic test after fabrication.

A nozzle modification program, or the B, D, DR, F and H Reactors will allow the use of a bumper fuel element. Grooves are broached in either side of the nozzle barrel to position the fuel element. Dye penetrant and hydrostatic testing at 900 psig follows. If the nozzle cannot satisfy these requirements, a replacement nozzle made of 6061 T6 aluminum alloy by an impact-extrusion process is substituted.

The standard inlet nozzle assembly of C Reactor is shown on Figure VI-8. This assembly is similar to the B, D, DR, F, and H Reactor assembly except that the flow monitor is located in the nozzle and the connector is 5/8-inch O.D. helically formed Inconel tubing. Dye penetrant, radiograph and hydrostatic tests were performed on these nozzles prior to installation.

In addition to standard inlet nozzles at C Reactor, there are three types of overbore (large) nozzles installed on the overbore tubes. Two of these, the "clamp" and "flapper valve" nozzles, are shown in Figure VI-9. New features of these two nozzle assemblies are: a neoprene bellows gas seal which can be replaced without removing the gunbarrel; a flow monitor with a

5. <u>F Reactor</u>

The F Reactor effluent system, shown in Figure VI-16, consists of one 60-inch carbon steel pipe line from the downcomer to the intake of the 107-F Retention Basin. From the outlet of the retention basin, the effluent system consists of one 60-inch by 1/2-inch thick wall, carbon steel pipe line which runs to the outfall structure. The outfall discharge to the center of the river is two 42-inch reinforced concrete pipe lines.

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AEC-GE RICHLAND, WASH.

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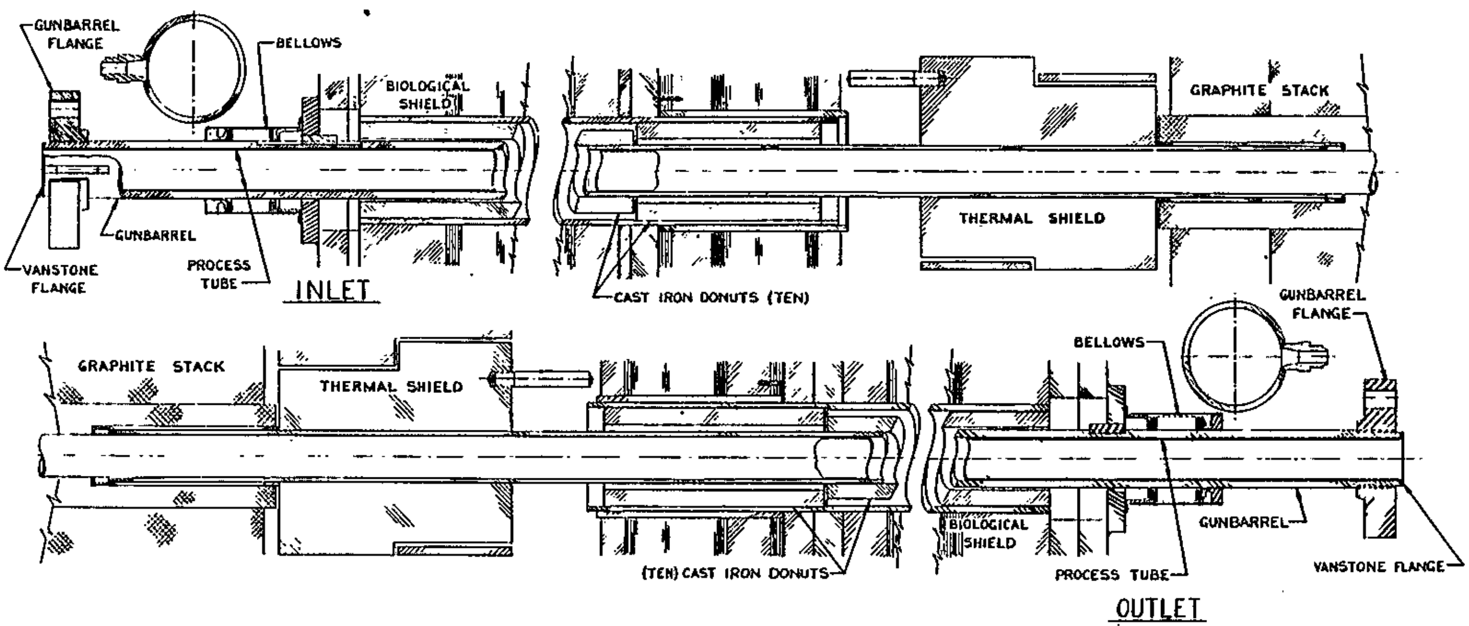

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FIGURE VI-5

Process Tube Channel Cross Section

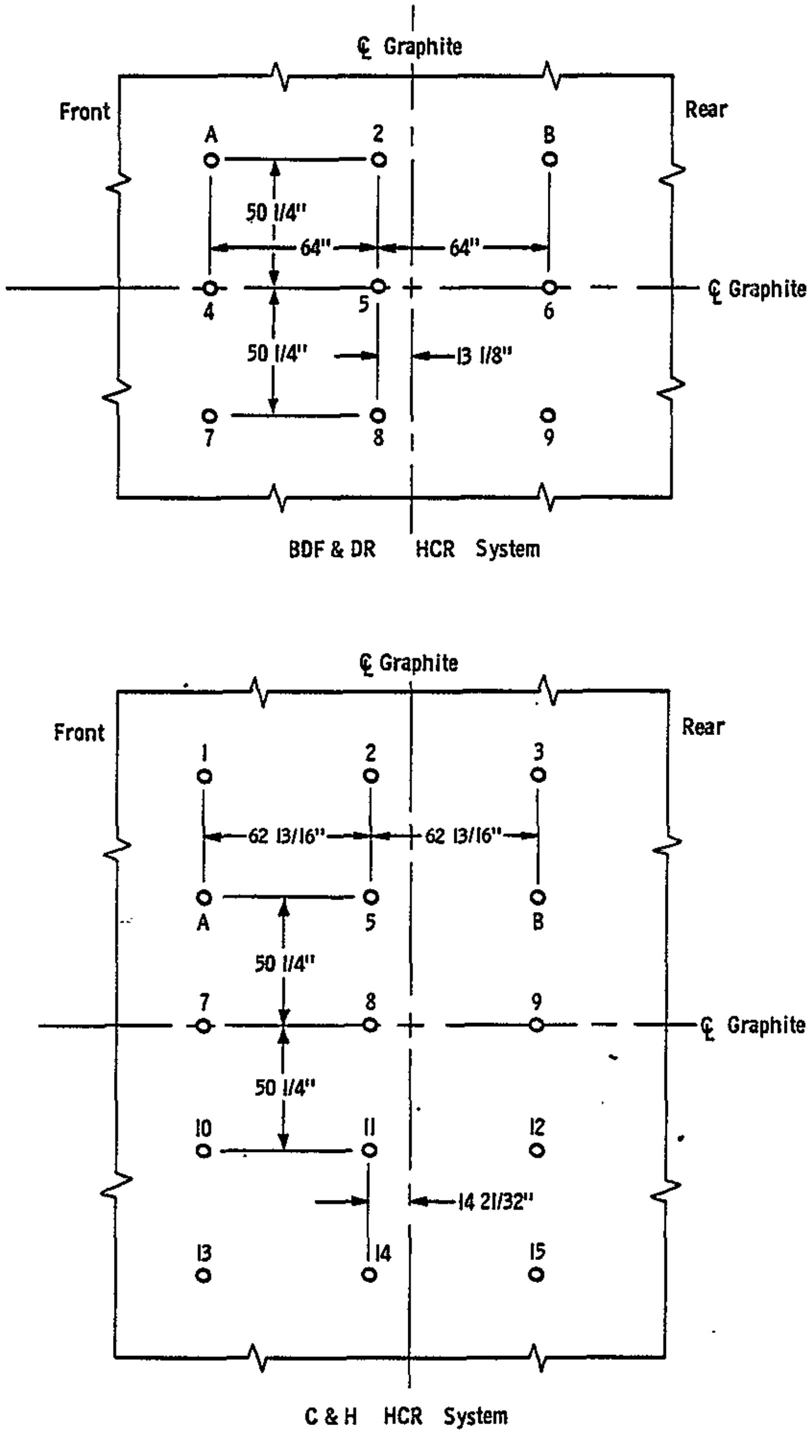

FIGURE VII-1
Horizontal Control Rod Arrangement

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C. Miscellaneous Systems

Three additional water systems, which are common to all of the reactors: the single-tube high-pressure water system; the solids feed system; and the hot water circulating system.

1. Single-Tube High-Pressure System

The single-tube high-pressure system is used for discharging poison column control tubes during operation and for flush discharging single process tubes. The system is made up of a 1-1/2- or 2-inch, Schedule 40, riser located on the side of the reactor front face, with valved outlets spaced approximately every six feet. The front face work platform has a 1-1/2- or 2-inch header, with valved outlets spaced approximately every five feet. To supply water to a single tube, the platform is positioned, the riser is connected to the header on the platform with a flexible hose, and in turn, the header is connected to the tube with a flexible hose. The system is supplied either by the reactor cooling water system or the high-pressure solids feed pump, depending upon the pressure desired.

2. Solids Feed System

The solids feed system injects a slurry of diatomaceous earth into the reactor cooling water to scour the corrosion film from the inner surfaces of the piping, the process tube, and fuel elements in order to reduce friction losses in the system. The diatomaceous earth slurry make-up tanks and the two high-pressure injection pumps, rated at 200 gpm at 700 psi, are located in the 105 Building Valve Pit at the B, D, DR, and F Reactors and in the 190 Building at the C and H Reactors. The point of injection is in the cooling water headers in the valve pit in the 105 Building. The capacity of the system is approximately 400 gpm, permitting a solids concentration in the reactor cooling water during a "purge" of from 25 to 50 ppm.

3. Hot Water Circulating System

A hot water circulating system is provided for drying out the graphite moderator during a period of reactor shutdown when the stack contains too much water to permit drying during reactor operation. The system recirculates hot water (150 - 200 F) through the process tubes, thereby heating the graphite and causing the water to vaporize and be removed with the circulating gas atmosphere system. The hot water is injected in the front risers, circulated through the reactor, and returned through the circulating pumps in the valve pit. The capacity of the system is 2000 gpm at the B, D, DR, and F Reactors and 1000 gpm at the C and H Reactors.

Heating for the hot water system is supplied from the 225 psi steam loop in 105 Building.

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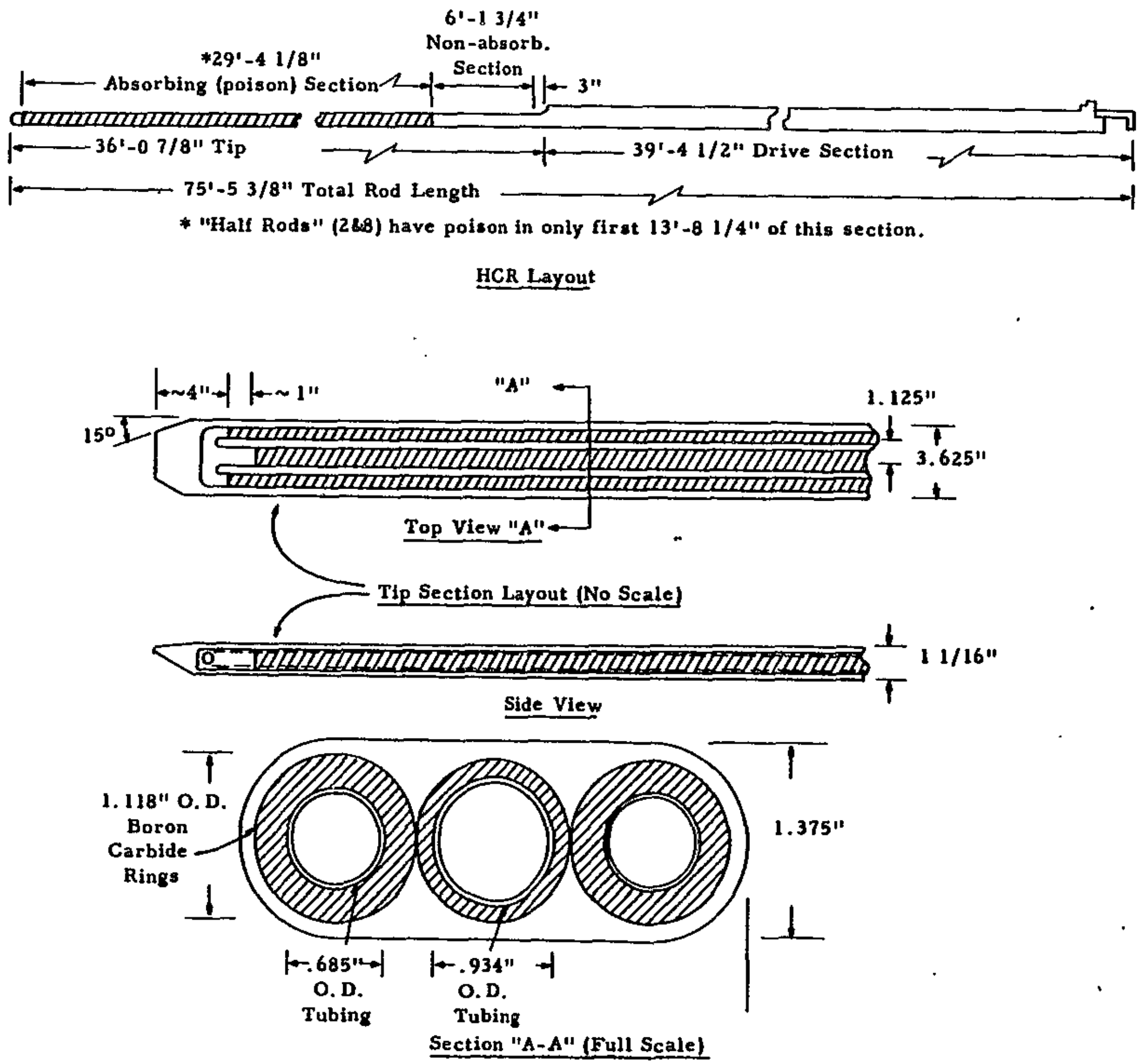
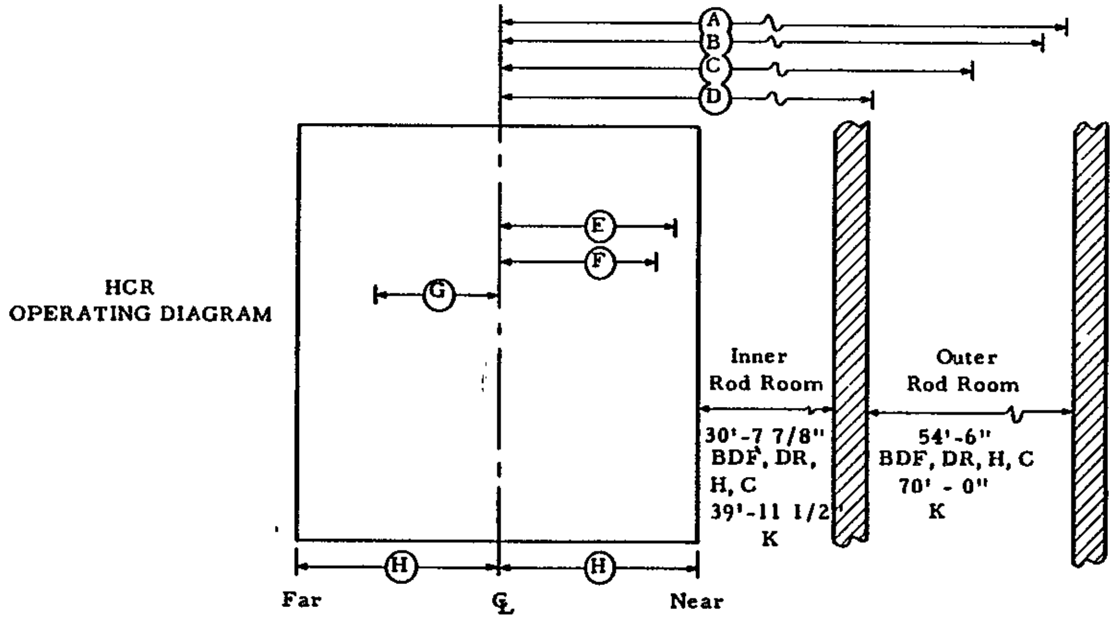


FIGURE VII-2

Horizontal Control Rods, B, D, DR, F, and H Reactors



KEY									
Dim.	**Code**	**B**	**C**	**D**	**DR**	**F**	**H**	**KE**	**KW**
A	Rod Full-out Position	95'-5 5/8"	98'-4 11/16"		95'-5 5/8"		95'-5 5/8"	112'-6 7/8"	
B	Rod Normal-out Position	93'-5 1/32"	95'-5 15/16"		93'-5 1/32"		93'-3 3/8"	108'-5 1/2"	
C	Rod Full-in Position	64'-7 1/32"	65'-3 15/16"		64'-2 27/32"		63'-3 3/8"	74'-1 7/8"	
D	Pile ℄ to Outer Rod Rm.	56'-0 1/8"	56'	Same as B	56'-0 1/8"	Same as B	56'	70'-0 1/2"	Same as KE
E	Rod-Tip Full-out Position	20'-0 1/4"	20'-8 3/4"		20'-0 1/4"		20'-8 3/4"	24'-7"	
F	Rod-Tip Normal-out Position	17'-11-21/32"	17'-10"		17'-9 21/32"		17'-10"	20'-5 5/8"	
G	Rod-Tip Full-in Position	10'-10-11/32"	14'-0"		11'-2 17/32"		12'-2"	17"-11 3/8"	
H	Pile ℄ to Outside of "B" Shield	23'-0 1/4"	23'-0 1/4"		23'-0 1/4"		23'-0 1/4"	27'-1"	
	Total Rod Length	75'-5 3/8"	77'-7 15/16"		75'-5 3/8"		75'-5 3/8"	92'-1 1/4"	

FIGURE VII-3

Horizontal Control Rods, Operating Diagram

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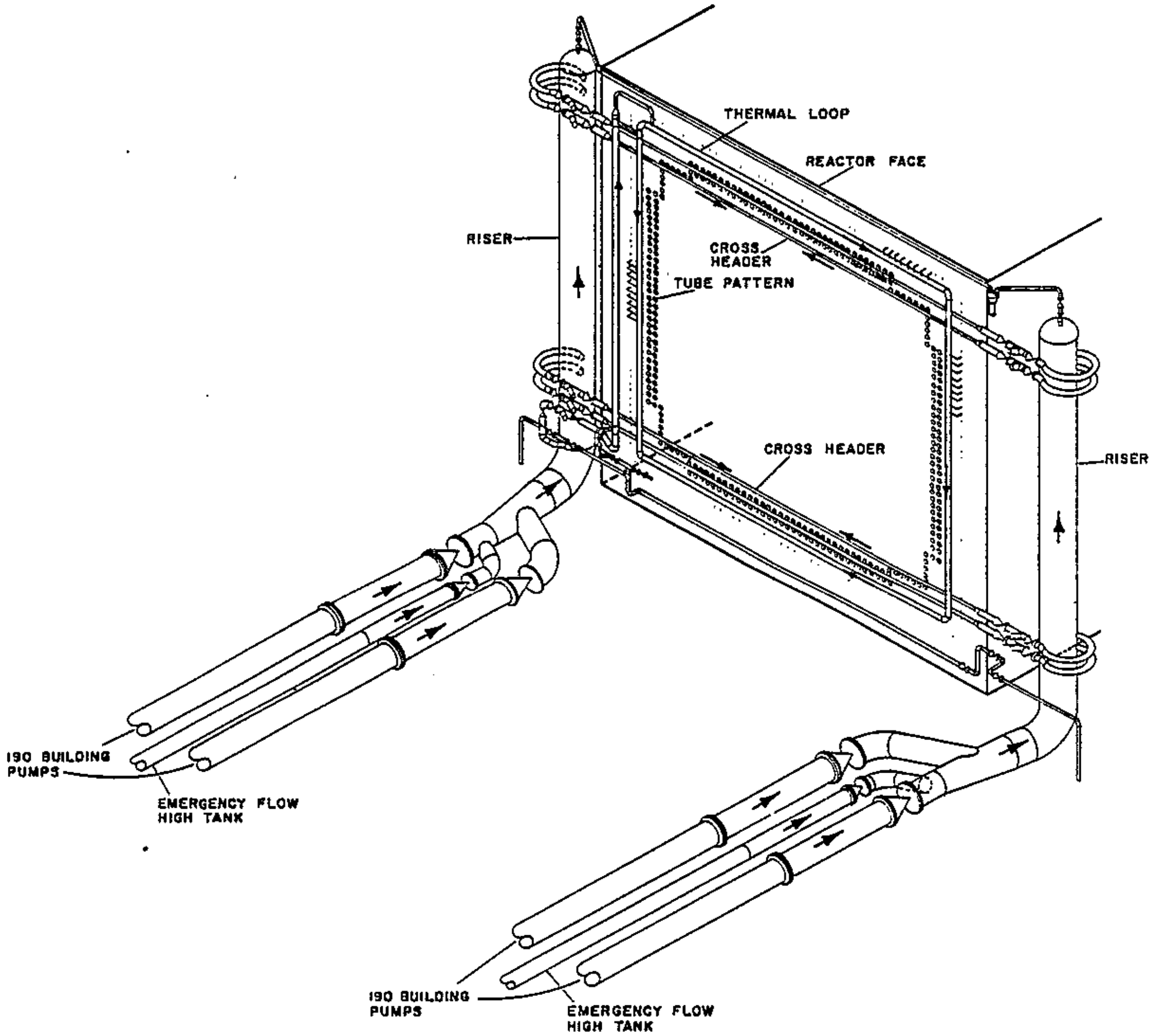

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FIGURE VI-4

Valve Pit to Inlet Nozzle Coolant Piping,
H Reactor

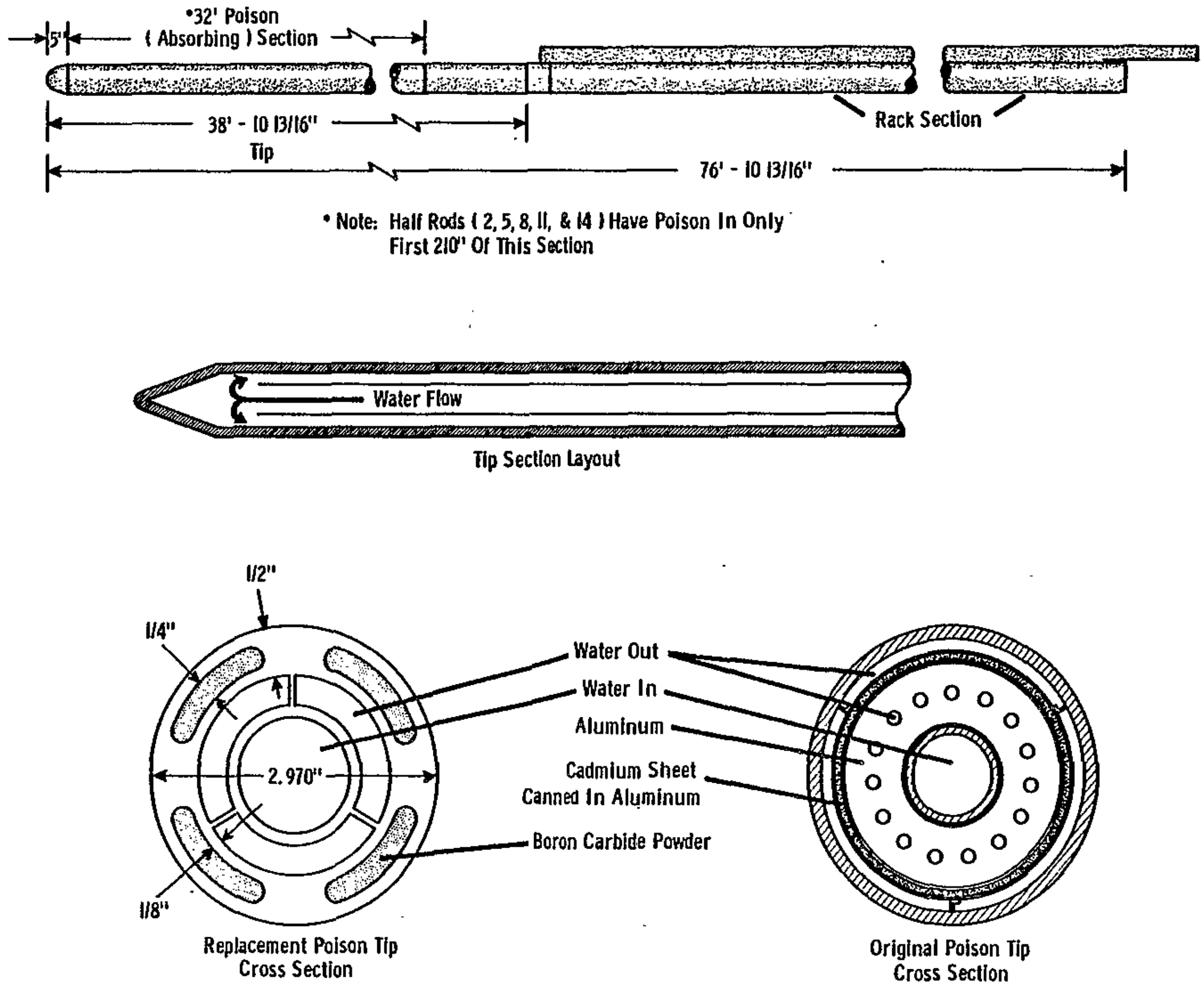

FIGURE VII-4

Horizontal Control Rod Assembly, C Reactor

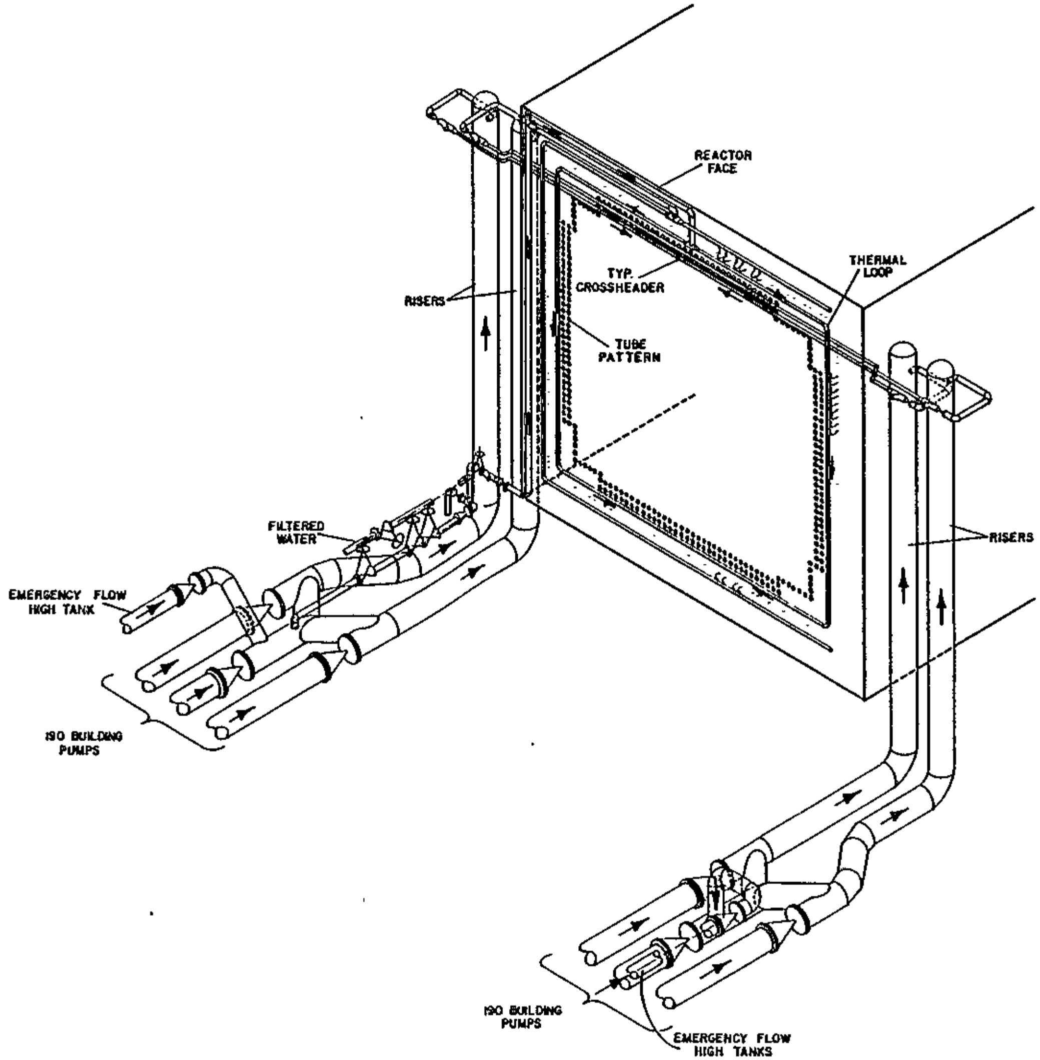

FIGURE VI-2

Valve Pit to Inlet Nozzle Piping, C Reactor

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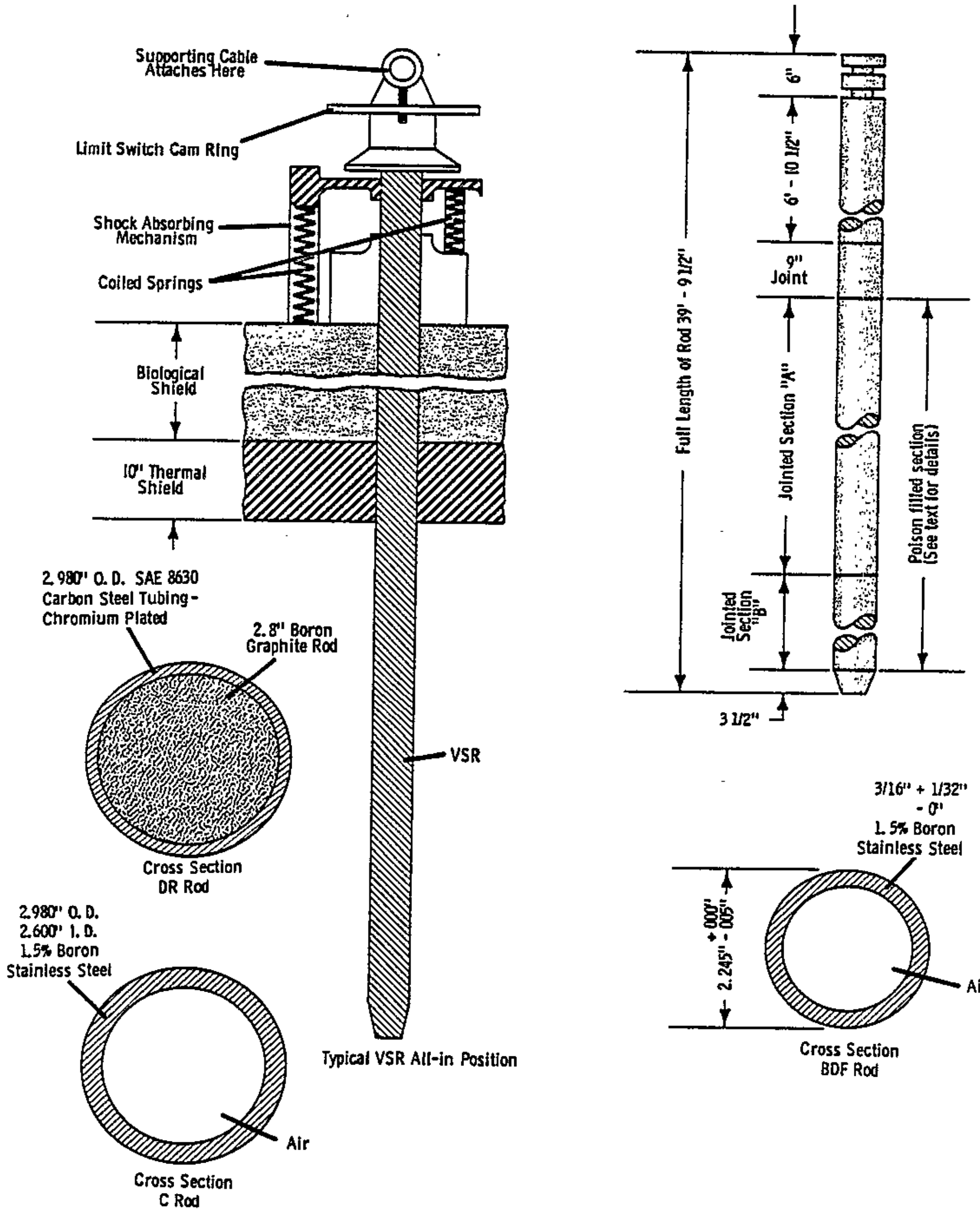

FIGURE VII-6

Vertical Safety Rod Structural Details

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VI. REACTOR COOLING

A. Reactor Inlet Piping

1. General

The original reactor inlet process piping at the B, D, DR, F, and H Reactors has been modified to provide for increased cooling water flow, higher pressures, and improved hydraulic efficiency. Essentially new piping systems were installed from the 105 Building Valve Pit to the front face crossheaders at the B, D, DR, and F Reactors. At the H Reactor, the pipe replacement was not as extensive and much of the original is still in use. At the C Reactor, no inlet cooling water piping changes were made.

The inlet piping of all reactors from the valve pit to the crossheader tube fittings is designed for a minimum non-shock, cold water, working pressure of 600 psi. In addition, the piping systems from the 190 Building cooling water pumps to the crossheaders were hydrostatically tested at 1-1/2 times the working pressure, or 900 psi.

The basic design of the inlet water piping systems of all reactors are alike. The pipe carries the water from the 190 Building cooling water pumps to the reactor front face and distributes it to the individual process tubes. There are, however, notable differences in the piping systems of the different reactors in arrangement, size, material, and pressure ratings of the pipe and valves. Because of the importance of the cooling water piping system to safe reactor operation, each system is described separately. In addition, the size, material, and pressure rating of each component in the reactor cooling water system, from the 105 Building Valve Pit to the inlet nozzles, is noted for each reactor in Figures VI-1, VI-2, VI-3, and VI-4.

2. B, D, and F Reactors

Cooling water pipe from the common crossheader in the 105 Building Valve Pit is divided into two 36-inch headers which run to the base of the reactor. Venturi tubes, which measure the water flow rate, are located in this straight pipe run. The high tank emergency water system ties into these headers downstream of the venturi tubes. The emergency system is isolated from the primary and secondary water systems by check valves.

At the base of the reactor, the water flow is directed upward through base ells to the 36-inch risers on both sides of the reactor face. The base ells are 36-inch, 90-degree, mitered elbows which have structural bases for supporting the risers. The water is then distributed across the reactor front face through 4-inch, Schedule 40, stainless steel crossheaders, which are connected to the risers at both ends. The riser-crossheader connection is made up of a 5-inch, Schedule 80, carbon steel, expansion loop; a 5-inch, carbon steel, 400# check valve; an insulating flange, a 5-inch, stainless steel, 400# strainer with an 8 x 8 mesh screen; a 4 x 5-inch stainless steel reducer; and a 4-inch, stainless steel, 300# gate valve.

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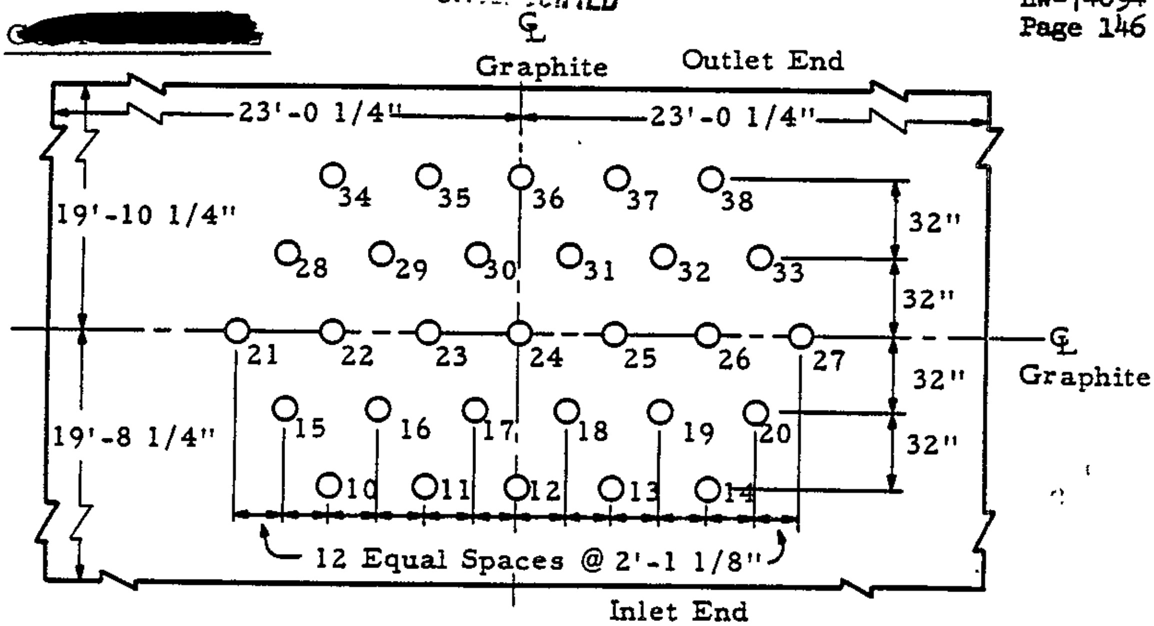
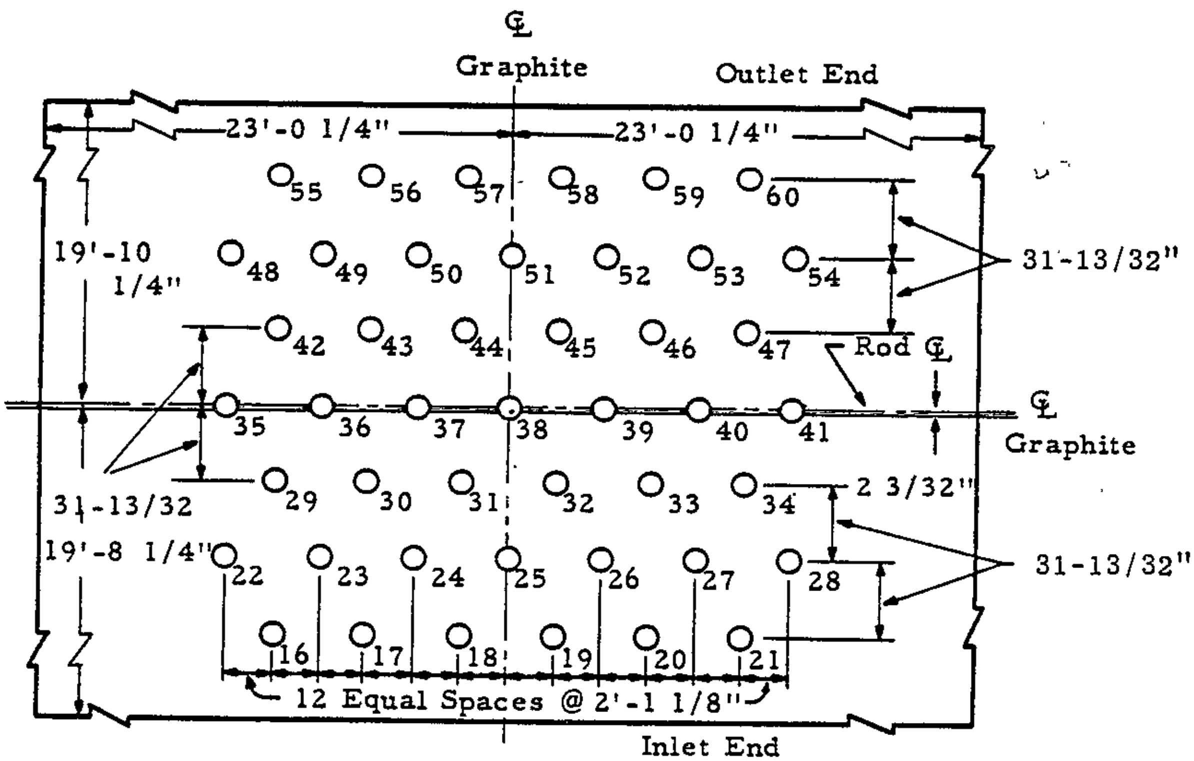


B, D, F, & DR VSR SYSTEM



C & H VSR SYSTEM

FIGURE VII-7

Vertical Safety Rod System Layout

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Ball 3X Backup Safety System has been installed at each reactor. The system requires no supplementary power supply and operates by gravity. The system utilizes both 3/8-inch and 7/16-inch diameter nickle plated boron steel, nickle plated carbon steel, and stainless steel balls which drop into the vertical safety rod channels upon trip of the Ball 3X circuit.

1. B, D and F Reactors

The Ball 3X systems at these three reactors are identical as shown in Figure VII-8. There are twenty-nine hoppers, each of which contains 925 pounds of mixed nickle plated boron steel and carbon steel balls, all 3/8-inch diameter.

The system is tripped manually from the reactor control room, or automatically upon rapid loss of cooling water pressure. Details of the 3X Safety Circuit are given in Section VIII - Reactor Instrumentation. Tripping of the 3X circuit causes rapid discharge of the hopper contents into connected VSR channels. The first balls reach the bottom of the channel approximately two and one-half seconds after a trip signal is initiated, and the channels are filled within 16 seconds.

Ball removal is accomplished by use of a vacuum system which, through the use of long tubes, lifts the balls from the bottom of the individual channels.

2. DR and H Reactors

The operation of the Ball 3X system in the DR and H Reactors is identical to the B, D and F Reactors as shown in Figure VII-8. However, slightly larger vertical openings were provided to further reduce the possibility of obstructed channels. These channels have a cross-section 4-3/16 inches square. The DR Reactor has twenty-nine ball hoppers and the H Reactor has forty-five. The weight of a full hopper of balls at each reactor is 1200 pounds. At DR Reactor, there has been enough stack separation and graphite breakage so that some balls have been retained in the stack structure after a spurious ball-drop.

3. C Reactor

The C Reactor has forty-five ball hoppers, each containing 1450 pounds of balls. The vertical channel is 4-3/16 inches square and is shown in Figure VII-9. Ball removal was simplified at C Reactor by the installation of valves on the face of the bottom biological shield. These valves are connected to the channel in the graphite by a pipe running through the bottom thermal and biological shield. The pipe is curved to provide shielding and the volume of balls in the hopper was increased to account for the volume of the pipe. Filling a VSR channel with balls takes slightly longer at C Reactor because of the time required to fill this pipe.

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100 psig supply make-up system, through a pressure reducing valve, to the circulation system.

Helium is received by railroad tank cars at 1800-3600 psig, and is unloaded through a pressure reducing valve which reduces the pressure to 700 psig. The cascade method is used for unloading; that is the storage tanks with the highest pressure are loaded first. When the pressure in the railroad car tanks is reduced to the storage tank pressure, a helium compressor is used to unload the remaining gas. The helium is transferred from the high pressure tanks to the 50 - 100 psig storage tanks. Through another pressure reducing valve the reactor gas circulation is supplied with make-up and purge gas at 1 to 30 inches water gage pressure.

The circulation system is a closed loop as shown on Figures V-6 and V-7. The flow through the system varies from a minimum of 100 cfm dry, 400 cfm wet, to a maximum of 1800 cfm, the capacity of the blowers. The gas pressure in the reactor is kept at the minimum positive value which will assure circulation and avoid in-leakage of air. The average pressure is less than 1-inch of water, and at normal flows, the pressure at the rear face outlet is 0.01-inch of water.

The gas system is protected from excessive pressure, or suction, by large liquid seal chambers connected to the recirculation lines. The pressure seal tank is set to relieve at 30-inches of water. The gas vented from this seal passes into the underground ventilation tunnel which leads to the exhaust stack. The liquid suction seal is set at minus 10-inches of water to protect the system in case the make-up valve fails to open.

The gas enters the reactor from a gas manifold beneath the unit through risers to the gas space between the thermal and biological shields on the front face. The gas flows through the reactor from front to rear through spaces in the graphite. The gas leaves the reactor through risers and a manifold similar to the inlet side. From the manifold the gas flows through a gas header in the gas tunnel to the 115 Building. A blower forces the gas through a heat exchanger where it is cooled before going through the silica gel dryer. After the dryer, the gas is filtered through the Airmat-type filters to remove foreign particles and any silica gel that is carried over. From the filter the gas flows to the reactor inlet manifold.

Three dryers are provided for each gas system; two are normally in service while the third dryer serves as a maintenance spare. In the dual reactor areas, B and C and D and DR, the third dryer is shared by the two gas systems. Of the two dryers in service, one dryer is on drying service in the recirculation loop while the other is being regenerated. During regeneration the blower forces gas through a heat exchanger which heats the gas to remove the moisture from the

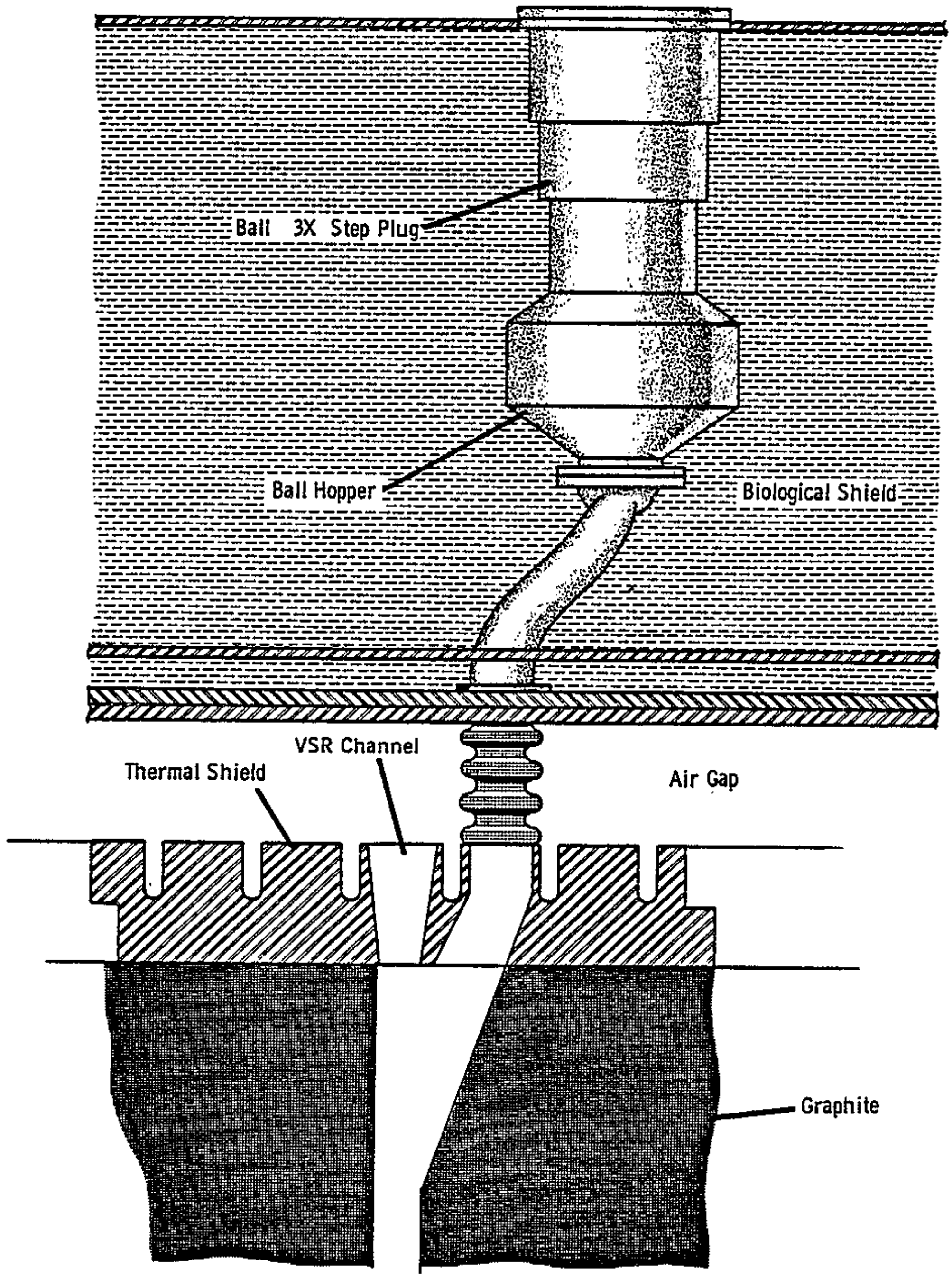

FIGURE VII-9

Ball 3-X Safety System,
C Reactor

E. Gas Atmosphere

1. General

The purpose of the gas system is to provide an inert, non-radioactive gas environment in the reactor to remove moisture and foreign gases from the reactor; to serve as the heat transfer media between the graphite and process tubes for the removal of heat from the graphite; and to detect water leaks within the reactor.

The reactor atmosphere is a mixture of helium and carbon dioxide with the composition varied and regulated to control graphite temperatures and reactivity requirements during operation. The purity of the gas mixture is also controlled to avoid detrimental effects of foreign gases such as oxygen and water vapor.

The gas system consists of equipment and piping located in the 105, 110 and 115 Buildings and in shielded connecting tunnels. The storage area, 110 Building, contains the high pressure and low pressure storage facilities for helium and carbon dioxide. The 115 Building contains the circulating gas blowers, silica gel dryers, filters, heat exchangers, valves, instrumentation and piping. The gas distribution manifolds, sampling lines, purge lines, and gas analytical equipment are located in the 105 Building. In the 100-H Reactor Plant there is no 115 Building and the equipment is located in the gas wing of the 105 Building. The volume of a closed loop reactor gas system is about 25,000 cubic feet.

Only the 100-B, D, F and H Reactor Plants have gas storage facilities, (110 Buildings). The C Reactor gas system is supplied by the B Reactor storage facilities, and the DR Reactor gas is supplied by the D Reactor storage facilities. Figure V-6 is a flow diagram of a single reactor gas system and Figure V-7 shows a flow diagram of a dual reactor gas system.

The water leak detection system of the reactor gas systems consists of 100 sampling tubes spaced evenly on the discharge face of the reactor and located in the gas plenum between the thermal and biological shields. Water from a leak within the reactor flashes into steam and is removed from within the reactor by the flowing gas stream. The location of the leak is then determined by measuring the water vapor in the 100 gas sampling tubes. Drip legs are also provided in the low points in the loop piping to remove liquid water which condenses from the gas stream. The seriousness of a leak can be determined by the rate at which water is collected in the drip legs. This water plus the water collected in the dryer beds following process tube leaks provides an estimate of how much water entered the graphite stack.

2. Operation of the Gas System

Carbon dioxide is received in liquid form and is transferred to liquid high pressure storage at 325 psig. The low pressure storage tanks at

b. Grey splines are used to increase flattening efficiency. These splines are only about 58 percent as effective as a regular spline and contain only about six percent B_4C.

c. Half splines contain about 15 percent B_4C in the downstream 19 feet of the spline. The remainder of the spline contains no poison.

d. Flux monitoring splines are a special purpose spline, 0.040 inches thick, which are inserted in the reactor for about 15 minutes in order to determine the flux distribution pattern from activation readings taken during their withdrawal.

The splines are utilized in conventional, ribbed, aluminum process tubes fitted with special inlet caps which allow for spline insertion and removal during reactor operation. The spline inserter is manually operated. Splines are removed with a spline coiler wihch is operated remotely from a radiation shielded area. The spline coiler removes splines at a maximum speed of 300 inches per minute which amounts to a change of 0.02 percent $\Delta k/k$ in 1.2 minutes and deposits the coiled, "hot" spline in a cask of water or into the water filled C work platform pit.

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Reactors and forty-five in the C and H Reactors.

2. Horizontal Control Rod Channels

These penetrations are located on the left side of the stack when facing the front face and estend through the process tube pattern in the stack. There are nine horizontal rod channels in the B, D, DR and F Reactors and fifteen in the C and H Reactors.

3. Experimental Test Holes

These penetrations are located in the right side of the reactor and are similar to the horizontal control rod channels. Some of the channels extend through the stack while others extend only into the core of the stack. Six test holes were provided in the B, D and F, seven in the DR, ten in the H, and fourteen in the C Reactors. These test holes are shown graphically in Figures XI-4, 5, 6, 7 and 8 and are described in Section XI.

4. Monitoring Penetrations

Instrument monitoring penetrations are located throughout the stack. The locations are described in the reactor control instrumentation section of this report.

D. The primary objective in reactor shielding is to ensure to operating personnel that exposure to radiation will not exceed long-term tolerance limits. Personnel is assured of this by a combined thermal and biological shield designed after determination of the bulk attenuation characteristics were predicted on the basis of iron-paraffin combinations and converted to iron-masonite full shield thickness by Fermi and Zinn in 1943.

1. Thermal Shield

Between the graphite stack and the outer biological shield is a layer of cast iron, designated as the thermal shield. The thickness of this shield varies by its location. Its thickness is 8-1/8 inches on the top, 8 inches at the sides, 10 inches in the front and rear, and 10-1/4 inches in the bottom. Approximately ninety-seven per cent of the gamma energy radiated from the stack is absorbed in this shield and converted into heat in the cast iron. The thermal shield is built of blocks which overlap each other at the edges so that no crack passes straight through. This feature contributes substantially to the effectiveness of the shield by eliminating the possibility of thermal "hot spots" in the biological shield or in the concrete base.

Cooling is provided for the top, bottom, and side shield by circulating water tubes imbedded in the blocks. The front and rear thermal shields

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VIII. REACTOR INSTRUMENTATION

A. General

There are three basic classifications of instrumentation within the reactor building.

The first can be defined as Reactor Safety Circuit Instrumentation. Instruments in this classification provide information on the status of the process by visual readout devices and are connected directly into the reactor safety circuits for automatic shutdown if established limits are exceeded.

The second is Reactor Process Control Instrumentation. These instruments provide information to operating personnel, as do those in the first classification, but do not have trip-out devices in the reactor safety circuits.

The third classification is Non-Process and Building Environmental Instrumentation. These are instruments used in the control of operations other than those directly affecting the operation of the reactor. They are located throughout the reactor building, in secondary functions such as monitoring radiation levels.

The important instrument characteristics and the important interlock and bypass conditions for safety circuits are tabulated at the end of this Section.

B. Reactor Safety Circuits and Safety Circuit Instrumentation

There are three separate and complete safety circuits in each reactor as shown in Figure VII-1. Each circuit is designed to initiate the insertion of a certain amount of negative reactivity into the reactor, either when the reactor exceeds preset limits or when a failure occurs within the circuit itself.

1. The IX Safety Circuit and Associated Instrumentation

The IX Safety Circuit is designed to scram the Vertical Safety Rods (VSR) and through an interlock, the SN relay, the Horizontal Control Rods (HCR). This is designated a Number One Scram. Only the negative reactivity of the VSR's is counted upon for reactivity control for this safety system. The safety circuits at the B, D, and F Reactors are 120-volt, AC circuits, while the C, DR, and H Reactors have 125-volt, DC circuits. In most arrangements, exceptions being noted in subsequent paragraphs, relays are used in parallel, with contacts connected in series to provide high reliability to trip on demand.

a. Manual Trip

A manual scram pushbutton is located on the reactor control console and is readily accessible to the reactor operator.

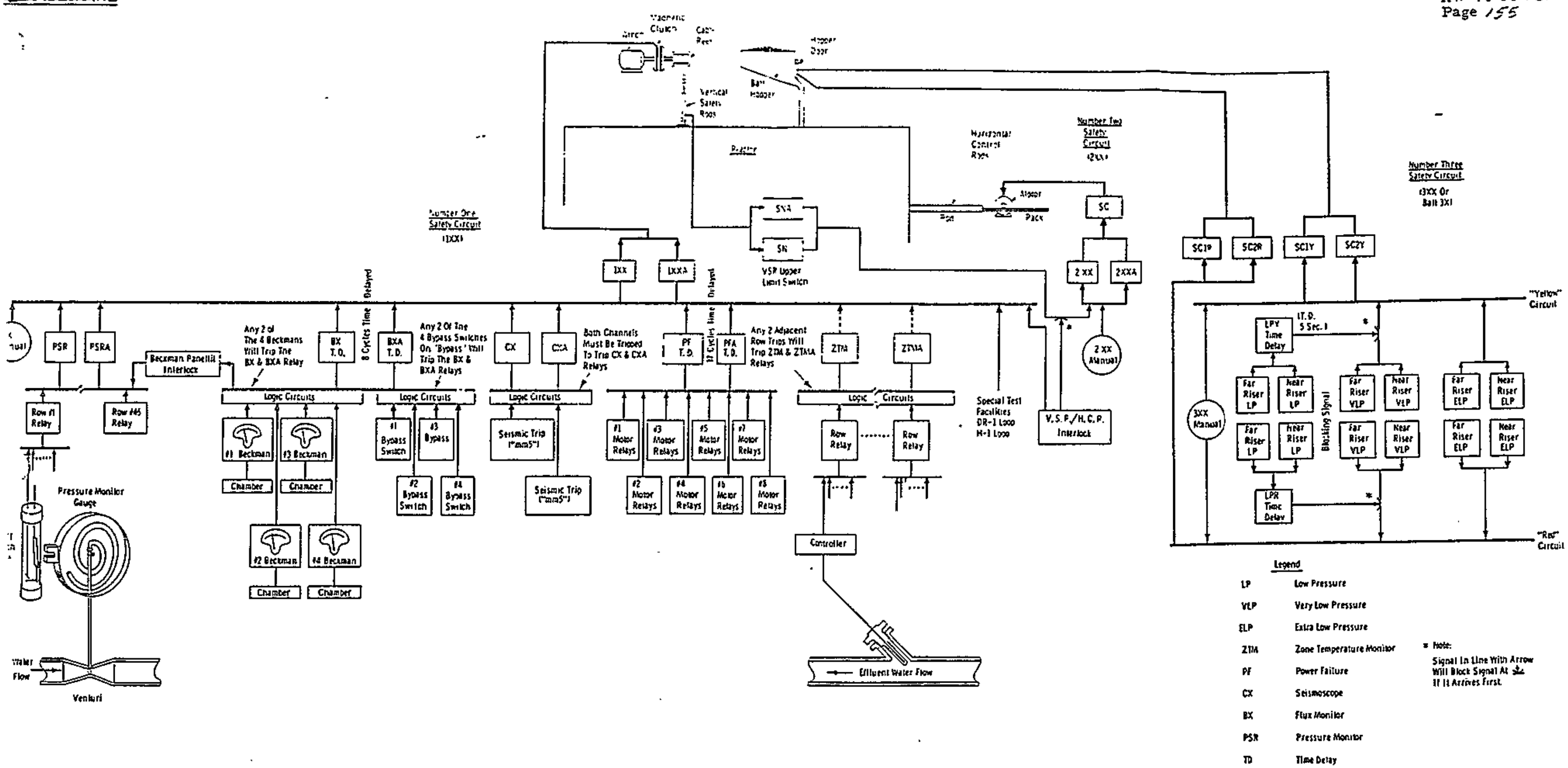

FIGURE VIII-1

Diagram of Three Safety Circuits at B, C, D, DR, F, and H Reactors

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b. Pressure Monitor

The Pressure Monitor System, sometimes referred by the gauge manufacturer's name, Panellit, measures coolant flow continuity in each individual process tube. There are 2004 tubes per reactor. A venturi, or a single or dual orifice, is located at the inlet of each tube, and from it a single hydrualic sensing line extends to the reactor control room and the pressure monitor gauge. Each gauge consists of a coiled Bourdon tube which rotates a dial through mechanical linkages. The pressure trip points, high and low, are set by positioning two magnets which are mounted on the dial and which operate an electric switch as they pass a metal "flag". This "flag" is attracted to the magnet, thus opening the switch contact. The individual contacts are summed into rows by single row relays which in turn trip the main system relays (PSR and PSRA).

Modifications are underway to change the present gauge switches from single-pole - double-throw (SPDT) to double-pole - single-throw (DPST) to permit a dual path tripping of the safety circuit. The number of relays will be reduced to six per circuit path for a total of twelve relays. Figure VIII-2, Coolant Pressure Monitor Circuit, shows the new system. This modification will provide individual gauge trip identification while present trip identification is by row only.

c. Neutron Flux Monitor

The Neutron Flux Monitor System, commonly referred to by the manufacturer's name, Beckman, is composed of fourpico-ammeters, ion chambers, and controllers for setting trip points. The four ion chambers are located in instrument risers beneath the reactor and are positioned for equilibrium power level calibration. The effective range of operation is the top four decades of the eleven decade range of neutron flux, from shutdown to equilibrium. Both high and low level trips are provided in the safety circuit. The coincidence of any two Beckmans in the tripped position will scram the reactor. Interlocks are provided so that bypassing more than one Beckman, or bypassing one and a trip on any of the other three Beckmans, will scram the reactor. The BX and BXA relays are time-delayed three to seven cycles, 60 cps reference, to permit amplifier recovery from short BPA power surges.

A "Beckman-Panellit" interlock is provided to automatically arm the Pressure Monitor when the reactor power level is above two megawatts. This circuit uses static switching devices in a one-out-of-four Beckman tripping circuit.

d. Seismoscope

Each reactor is equipped with three seismoscopes. Two are connected to the Number One safety circuit, and both must trip to produce a scram.

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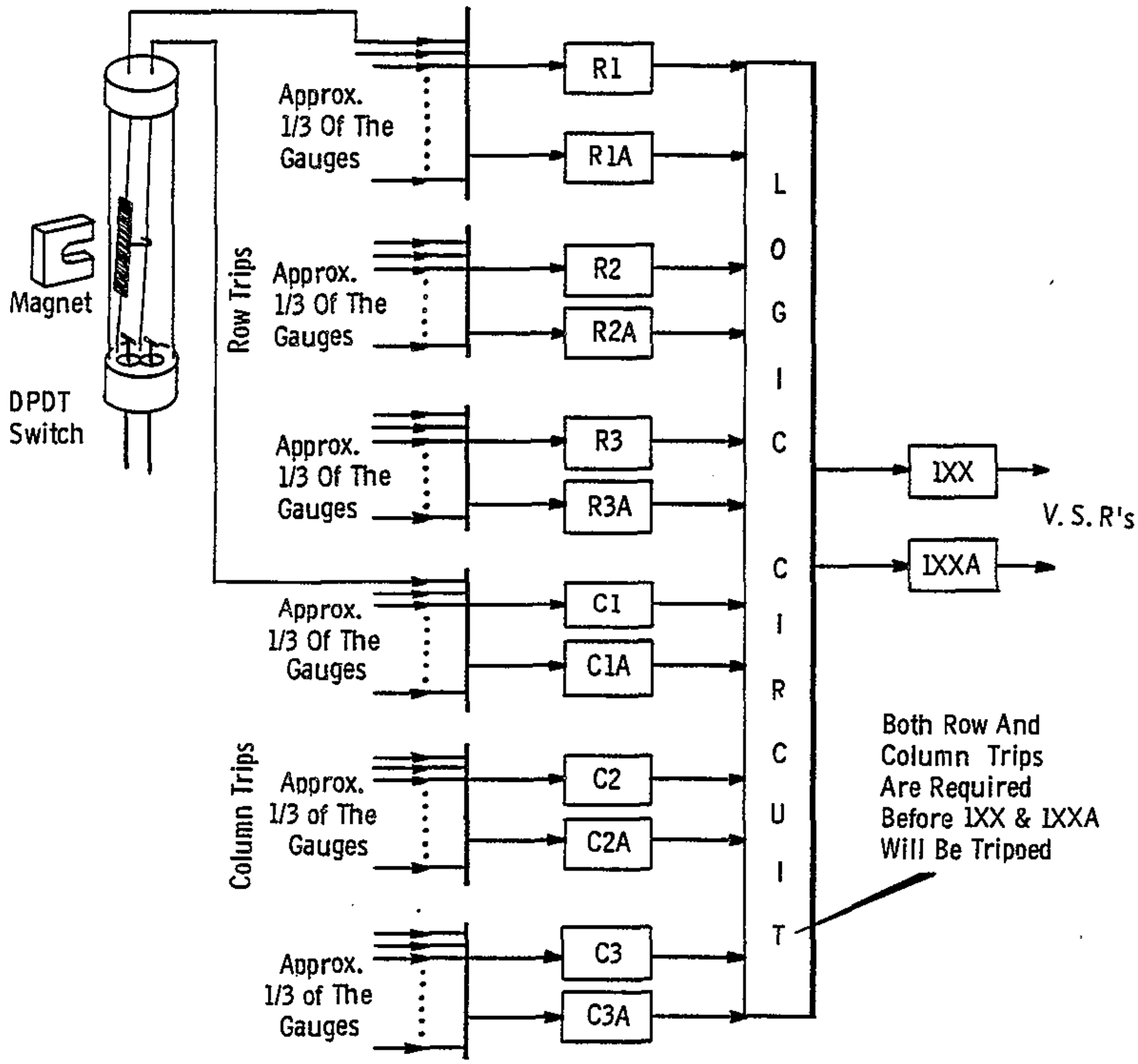

FIGURE VIII-2

Coolant Pressure Monitor Circuit

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They are set to trip and annunciate on a Modified Mercalli scale of 5. The third seismoscope is set at MM2 and is used as an information device with annunciator only. A modification program is underway to set it at MM5 and require a signal from two out of the three seismoscopes to trip the Number One Safety Circuit.

e. Power Failure

Detection of pump power failure trips the reactor safety circuit through the motor protection relays in the 190 Buildings. The PF and PFA relays are time-delayed seventeen cycles to allow overriding short BPA power surges.

f. VSR/HCR Interlock

The VSR/HCR interlock prevents the removing of HCR's from the in-core position before the VSR's are withdrawn; also, if the VSR limit switches are bypassed, a Number One Scram is initiated.

g. Zone Temperature Monitor

The Zone Temperature Monitor is being modified and testing is underway to establish the feasibility of connecting it into the 1X Safety Circuit. This system is composed of Resistance Temperature Detectors (RTD), controllers, and a visual readout display. The RTD's measure the temperature of the outlet water from the center process tube in a group of nine tubes (3 x 3 tube array). Measurements are taken of 211 different, nine-tube zones. Each controller has an adjustable trip setting range corresponding to 85 C to 140 C. The system can be set to initiate a Number One Scram when any two adjacent RTD's exceed limits.

h. Master Relays

There are two master relays in the 1X safety circuit which are the 1XX and the 1XXA. These relays have their coils in parallel and their contacts in series. The relay contacts control the VSR clutches. With the coils in parallel and contacts in series, operation of either relay releases the VSR's, thus emphasizing safety rather than continuity of operation. The rods are released if power is lost to either the 1XX and 1XXA relay coils or to the safety circuit itself. There are no switches for bypassing the 1XX or 1XXA relays.

2. The 2X Safety Circuit and Associated Tripping Devices

The 2X Safety Circuit scrams the horizontal control rods only. This is designated as a Number Two Scram.

a. Manual Trip

A manual scram pushbutton is located on the reactor control console and

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is readily accessible to the reactor operator.

b. VSR Limit Switch

The upper limit switch from each VSR is connected through the SN and SNA relays to scram the HCR's if a VSR should inadvertently drop into the reactor.

c. HCR/VSR Interlock

An interlock is provided to keep the 2X Safety Circuit (HCR's) in the tripped position, HCR's inserted, until the VSR's have all been raised prior to startup.

A 2X Safety Circuit trip causes only certain HCR's to drive in. At the B, C, D, DR, F and H Reactors, the rods which drive in on a Number Two Scram are those horizontal control rods which are not half-rods. Any horizontal control rod can be taken out of the 2X Safety Circuit by operating a bypass. The number and location of the rods which must scram is governed by procedure.

The Number One and Number Two Scram Circuits are connected by the SN and SNA relays. A Number One Scram causes the SN and SNA relays to operate, which in turn signals a Number Two scram. The reverse cannot occur, and a Number Two Scram does not cause a Number One Scram.

3. The 3X Safety Circuit and Associated Instrumentation

The 3X Safety Circuit controls the backup Ball 3X system. This scram is designated a Number Three Scram. The 3X Safety System can be tripped manually or automatically if the potentiality of a significant coolant loss is detected. The automatic trip signal is from a set of Mercoid pressure switches located in each inlet riser. There are three settings used: Low Pressure (LP), Very Low Pressure (VLP), and Extra Low Pressure (ELP). The LP and VLP trips are set to scram the Ball 3X system upon a pressure decay faster than a fixed rate. This is accomplished by a time delay coincident trip of the LP and VLP switches. The ELP trip will automatically trip the Ball 3X system when the pressure drops below a fixed minimum.

There are two complete circuits in the 3X Safety Circuit, called the red and yellow circuits, which must trip in coincidence to initiate a scram. This allows a failure of any component, pressure switch, relay, or solenoid latching mechanism, in one system without tripping the Ball 3X system. A manual pushbutton is centrally located in the control room to actuate both the red and yellow circuits.

The SC1R, SC2R, SC1Y, and SC2Y relays operate when any of the above trip. (The designations R and Y stand for red and yellow, respectively.) Operation of these relays opens the hopper doors allowing the balls to enter the reactor. The SC1R and SC2R and the SC1Y and SC2Y relays have their coils in parallel and contacts in series. Each ball hopper door is equipped with two latching relays, one being operated by either the SC1R or SC2R and the other by the SC1Y or SC2Y. For a ball drop to occur, both a yellow and red circuit relay must operate. None of the SC relays have bypass switches but bypass switches are provided for the VLP and ELP trips. Normally, the ELP switches are bypassed and are activated only in case of an evacuation. The VLP switches are also provided with a key-lock bypass. The VLP is bypassed during a normal reactor shutdown process to prevent an unnecessary ball drop. Bypassing the VLP's is annunciated on the annunciator board.

Individual VSR's and Ball 3X Hoppers can be manually locked out but the number is limited. For example, it is common practice to lock out the ball hoppers during a reactor outage if adequate control elements have previously been inserted into the reactor. The lock-bars must be removed before the VSR's can be withdrawn for a startup.

4. Response Times of the Three Safety Circuits

The response times of the many components comprising the three safety circuits are tabulated at the end of this Section.

C. Reactor Process Control Instrumentation

Instrumentation, other than that used for safety circuit action, is necessary if the reactor is to be controlled efficiently. In some situations, manual scramming of the reactor is required when indicated readings reach predetermined values.

1. Nuclear Instrumentation

The nuclear instrumentation range requirement is from normal background or shutdown flux levels to approximately one hundred billion times normal background. A single instrument is not presently available with this large a range. This requires that instrumentation be divided into different systems which monitor reactor operation at various flux levels.

a. Low Level Neutron Flux Monitor

At background or shutdown levels, the Low Level Neutron Flux Monitor System (Subcritical Monitor) is used. This system is comprised of two separate and identical channels, each composed of a fission chamber mounted on a screw-driven mechanism and an amplifier-counting circuit, indicating period and level. The system is set to provide visual and audible alarms when a fifteen-second rising period is reached. The primary use of this system is to determine when the reactor achieves criticality and to indicate the magnitude of the rising period during low power level operation at startup.

The range of each channel is a nominal five decades with an effective four decades. During startup, the channels are used in tandem with overlapping range settings to extend the system range to approximately nine decades. This is accomplished by withdrawing the chambers, in steps, from their full-in location at the moderator fringe. Figure VIII-3, Effective Flux Ranges of Nuclear Instrumentation, shows the relationship of this system to the other nuclear systems.

b. Galvanometer System

The galvanometer system operates from a current source of from one to eight neutron sensitive ion chambers, depending upon the reactor. Two galvanometers are connected in series; one providing a signal (deflection) proportional to neutron flux power level and the other showing deviation from a preset level. The readout equipment, including shunts and potentiometers, is located at the reactor control console. This signal is used for operational monitoring and is not connected to the safety circuit.

c. High Level Neutron Flux Monitor

The safety system nuclear monitoring system (the Beckmans) was previously discussed in the Section on Safety Circuits. The B and C Reactors use the Model V Beckman picoammeters currently in production, whereas the D, DR, F, and H Reactors still have the RXG-2 Beckmans which have not been manufactured for about nine years. In most cases, the latter instruments have been modified due to a lack of available spare parts for these units. Signals are derived from four chambers located near under-reactor risers; their readings are therefore redundant.

The instrument scale ranges from 10×10^{-13} to 10×10^{-8} amperes. Trip settings are controlled by procedure and at full level are a fixed ten per cent above the instrument reading.

d. The Octachannel Flux Monitoring System

The C Reactor is the only one of the six older reactors equipped with a flux monitoring system with eight channels for monitoring the eight corners of the reactor. The chambers are placed in holes located in the side-shields of the reactor. They are not compensated but have been made neutron sensitive by the use of a boron-coated electrode. The current from an individual chamber is fed to a metering circuit and recorder which indicates the difference between the individual current and the average of all eight currents. The combined currents from all eight chambers are fed to the Galvanometer System. The Octachannel System is used for information rather than safety circuit activation.

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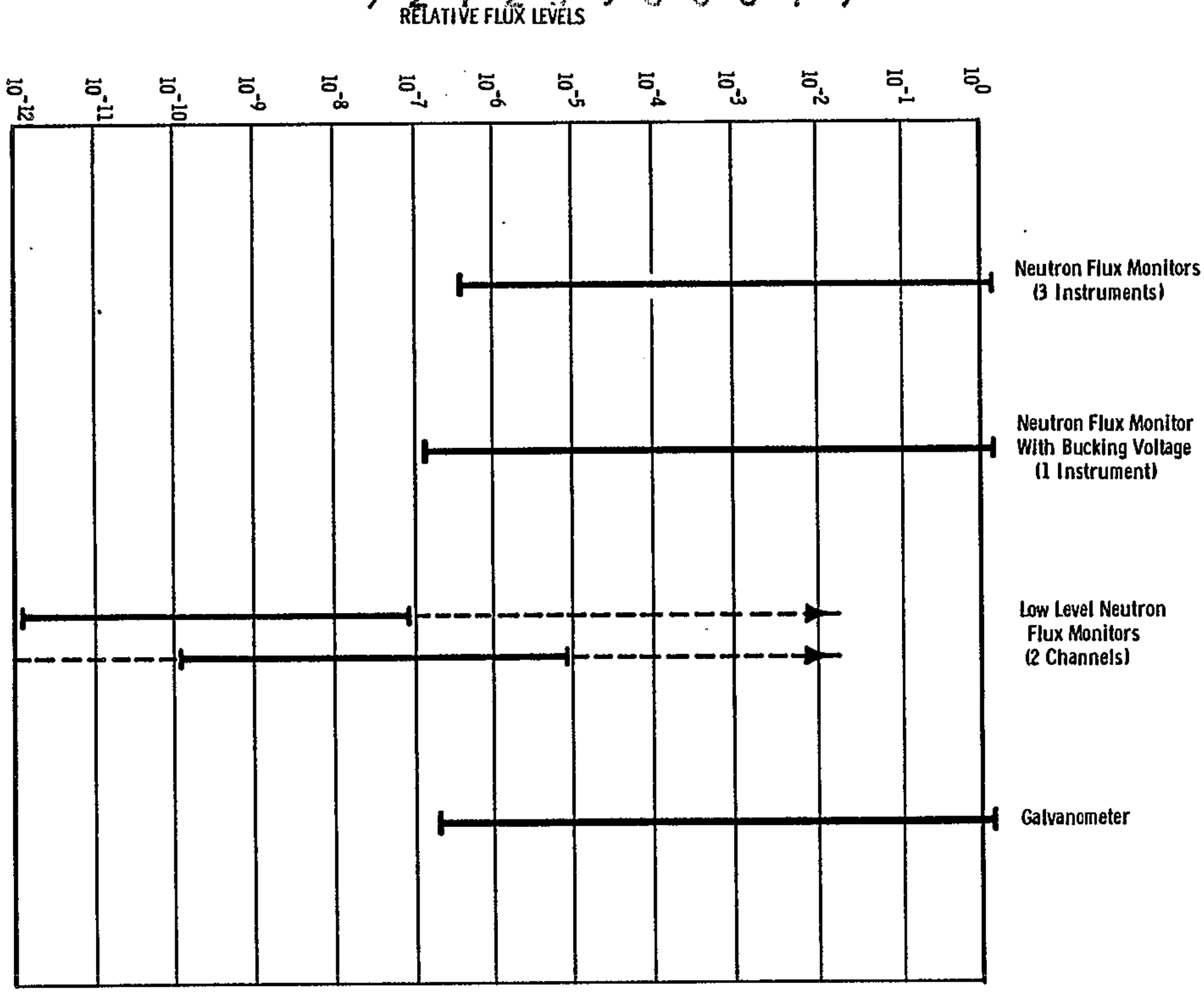

FIGURE VIII-3

Effective Flux Ranges of Nuclear Instrumentation
(Typical for B, C, D, DR, F, and H Reactors

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2. Temperature Monitoring

Temperature monitoring is divided into three categories of instrument systems; effluent water temperature monitoring; moderator temperature monitoring; and thermal shield temperature monitoring. There are many different methods for displaying this information to operating personnel. Generally, the main temperature monitoring functions are similar in all reactors.

a. Effluent Water Temperature Monitoring

A thermocouple is installed at the outlet end of each process tube to measure the temperature of the cooling water leaving that tube. Each thermocouple is connected to a plug board in the control room and a series of stepping relays is used to scan the thermocouples by rows, in process order.

The plug board is used to manually select individual tube temperatures for recording data in various forms. Two recorders are provided for individual trend-recording of temperatures; one, for traversing selected tube temperatures in process tube order, and one, for recording the temperatures from a preselected number of tubes which are representative of different zones in the reactor, and signaling any in excess of a variable set point.

Stepping relays select thermocouples in reactor format sequence by rows for recording by an electric typewriter, or on the traverse recorder mode. A mechanical analog-to-digital converter (ADC) changes the analog voltage from the thermocouple to a digital signal for the typewriter. Modifications are to be made to change the mechanical ADC's to solid state, electronic devices.

Reactor bulk water temperature is measured by means of an RTD (Resistance Temperature Detector) located in the reactor downcomer. At those areas with two downcomers, a RTD is located in each. This temperature is recorded in the control room and is also used in the power calculator.

A linear power rate-of-rise system operates from Resistance Temperature Detectors (RTD's) located at the outlet of ten process tubes rather uniformly distributed over the rear face of the reactor. The circuit averages and then differentiates the signals of the RTD's to show the linear increase or decrease in average power level, in megawatts per minute.

The Zone Temperature Monitor is a separate system composed of 211 zones or temperature cells as discussed previously.

b. Moderator Temperature Monitoring

Thermocouples were originally embedded in the moderator to measure the

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distributed temperature of the graphite. Because a large percentage of these original thermocouples have ceased to function, it has become necessary to provide another means for obtaining this temperature information. Eleven thermocouples were placed in stringers of graphite beads and inserted in process tube channels. As these stringers cease to operate, they are removed and replaced with other units. There are seven channels with graphite thermocouple stringers in each reactor. A new method, recently devised, permits insertion of sheathed thermocouples in the tube channels without the graphite beads. The temperature information is presented on profile recorders, or can be read out directly by a trend recorder through a plug board.

c. Thermal Shield Temperature Monitor

Thermocouples are distributed in the thermal shield to maintain temperature control. Shield temperatures are limited to minimize thermal deterioration of the biological shield masonite.

3. Miscellaneous Coolant Water Instrumentation

There are many miscellaneous pressure gauges in the control room which indicate the pressures at various points in the primary and secondary coolant systems. Included in these measurements are top of inlet riser pressure, crossheader pressures, top of downcomer pressure, control rod coolant pressures, and high tank level and pressure.

4. Gamma Monitor

The Gamma Monitor System detects fuel element failures. It continuously samples effluent water from each rear crossheader. A scintillation counter scans the effluent stream samples and measures the rate of gamma emission in the energy band of 2.1 to 3.2 mev emanating from the fuel element debris. The measuring system is compensated for power level by using N^{16} activity as a reference. Visual and audible alarms annunciate if trip points are exceeded. The radiation profile of the crossheaders is also plotted on multipoint recorders.

5. Reactor Power Level Calculator

The total power level of the reactor is computed by a calculator using total flow to the reactor from the 190 Building and the bulk coolant temperature increase across the reactor. The total power level is recorded on a circular chart and power deviation from a preset power level value is recorded.

D. Non-Process and Building Environmental Instrumentation

General

Instrumentation is required in parts of the reactor building to support work which is not directly associated with the nuclear reactor process. No national standards are known for this application. The AEC manual for Licensees is not followed due to the very low alarm trip limit imposed. Trips at the Hanford Reactors are set at twenty-five per cent above the background level, except for critical radiation alarm systems which are set a 1 r/hr to 5 r/hr depending upon the equipment used. This variance is due to the differences in equipment being used for this purpose. Radiation background and the movement of miscellaneous sources of gamma radiation make a meaningful trip point lower than 1 r/hr impractical. The critical radiation alarm is a motor-driven howler. The intermediate level alarms, where used, are vibrating horns and in some locations vibrating horns and rotating flashing lights.

The action required by personnel upon the actuation of the critical radiation alarm is immediate and rapid evacuation of the affected location. The action required upon actuation of the intermediate level radiation alarm is immediate evacuation of the location. The immediate responsibility in the event of a critical radiation alarm rests with the supervisor in charge of the facility.

Sensors are required at all locations where the radiation background would be sufficient to deliver a dose greater than 1 mr/hr to personnel occupying the location or where there is a potential for inadvertently exposing personnel to high radiation dose rates.

The ionization chamber used at all reactors is of HAPO design. It has a tissue-equivalent wall with a density of 440 mg/cm^2 and the following physical dimensions: 12.06 cm in diameter and 43.18 cm in length (volume, 1638.33 cm^3). It is an unpressurized air chamber. The current output of the chamber is 3.3×10^{-11} amperes/roentgen hour. The current measuring capability of the electrometers in use is from 1×10^{-13} to 10×10^{-8} amperes divided into six linear ranges. All systems are operated by the reactor plant power system with emergency power backup.

The following is a tabulation of monitored locations in the F Reactor building, which is typical for all of the six older reactors.

All chambers are HAPO developed health monitoring (HM) chambers. All amplifiers are Beckman RXG's. Micromax recorders are used unless otherwise indicated.

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F REACTOR MONITORING SYSTEM

Recorder Point	Chamber Location	Recorder Location	Remarks
1	"C" Work Platform	Control Room	4 chambers in series, intermediate alarm off controller
2	Dummy Elevator		
1	Rear Face 0' Far	Control Room	
2	Rear Face 10' Far		
3	Rear Face 20' Far	Control Room	Controller with critical alarm
1	Transfer Area	Control Room	
2	Loading Pit		
3	Instrument Rooms		
4	Top of Unit		
1	"D" Mach. Room Near	Control Room	
2	"D" Mach. Room Far		
3	10' Storage		
4	Cushion Corridor		
1	Discharge Chutes	Control Room	
2	10' Near - Discharge Area		
3	20' Near - Discharge Area		
4	30' Near - Discharge Area		
1	20' Far - Discharge Area	Control Room	Interlock w/chg. mach., Rear doors, Red flasher alarm, Speedomax 1 point recorder
1	Control Room	Accumulator Room at -12'	
3	Hose Reels (Outer Rod Room)		
4	Inner Rod Room		
3	Work Area	Zero Far	
4	X-1 Level		
1	Work Area - Critical	None	Critical alarm
1	115 Control Room	115 Control Room	
1	Metal Storage		Critical alarm
1	Storage Area	None	Critical alarm

Critical radiation alarms are placed in those locations where unirradiated enriched fuel elements or irradiated fuel elements are stored. The alarm system consists of an ion chamber, electrometer, recorder, and motor-driven horn. The ion chambers and horns are located overhead where possible and away from the entrances of the facility.

The coolant effluent monitoring system within the reactor building detects fuel element failures. Coolant samples from various portions of the rear face piping are monitored by scintillation chambers. This instrumentation is equippped with alarms and recording devices. Ionization chambers over the retention basins detect and record gross changes in the amount of radioactive material in the effluent.

E. Instrumentation Power Supply

The electrical power supply system is described in detail in Section IV. BPA power is supplied through the distribution system to the reactor building and its distribution system. If normal BPA power is lost, emergency power to critical instrumentation is immediately provided by station batteries at the C, DR, and H Reactors. When the steam turbine generator in the 184 Building starts, in twelve to fifteen seconds, the emergency electrical load is automatically transferred to that emergency power supply. At the B, D, and F Reactors, a 10 KVA gasoline engine-generator starts upon loss of normal power. It is delayed about twenty seconds to allow the power from the 184 Building to take up the electrical load. If that power supply should fail, the gasoline engine generator will provide a third source of limited electrical power. In all of the B, C, D, DR, F, and H Reactors, the Ball 3X systems are independently powered by station batteries which provide power at all times. These batteries are kept fully charged by normal power and, in effect, "float" on the line.

F. Reactor Communication System

Although the reactors vary in specific details from each other, a total communications system can be described by dividing the system into general categories of subsystems.

The Teletalk Subsystem has stations placed throughout the reactor building and operates from 110 volt emergency power wall receptacles. Each station is comprised of a combination microphone-speaker, a volume control, an amplifier, and selector switches. Any station can select and communicate with any other station.

The C-D Subsystem located on the charge-discharge work platform, is primarily used during charge and discharge of the reactor and for reactor maintenance functions. Each station consists of a microphone and speaker. The microphone transmits directly to all stations so information is heard at all work locations. The C-D and Teletalk Systems indirectly back up each other since many points in the building are common to both systems.

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A paging system is provided to allow messages to be sent to personnel in all locations in the building. Microphones are located in the control room and supervisor's office.

Several special purpose communications subsystems have been installed so that more than one work conversation over the same system will not give conflicting information at other locations. Included in this category are the Ball 3X subsystem, the radiation monitoring timekeeping subsystem, and the various sound plug-in subsystems. Direct sound power communication has been installed between the reactor control room and the 190 Building, the 151 Building, and the 107 Effluent Basin.

Regular plant dial telephone communication is available to and from all 105 buildings. Telephones are located in all control rooms and supervisors' offices, plus eight to twelve additional locations scattered throughout the building.

A television system has been installed at the B and C Reactors for monitoring work activity on the front and rear faces of the reactor. The receivers and camera controls are located in the control rooms and supervisors' offices. The remaining reactors will be equipped with portable cameras with pan and tilt tables and zoom lenses, two portable monitors with remote camera controls, and the means for moving this equipment through the building.

REACTOR INSTRUMENTATION DETAILS

System	Description	Location	Sensitivities or Response Characteristics	Design Information	Readout	Alarms or Action
1. Neutron Flux						
(a) Beckman Flux Monitor	Uncompensated ion chambers (four).	Under central section of reactor and beneath the openings of risers.	$4 - 6 \times 10^{-15}$ ampers per nv.	G.E. Mark II or equivalent. Boron-coated chambers.	Current metered and recorded for each chamber.	Light and alarm on exceeding high or low trips. Trips #1 Safety Circuit during reactor operation.
(a) Galvonometer No. 1 & No. 2	Uncompensated ion chamber.	Test hole on far side of reactor[a].	6×10^{-15} ampers per nv.	G.E. Mark II or equivalent. Boron-coated chambers.	Total and deviation current metered.	None
(c) Low-Level Neutron Monitor	Two Fission Counters with controlled positioner.	Test holes on far side of reactor.	$1.5 - 1.5 \times 10^5$ nv is operable range of sensitivity.	Reuter-Stokes, type RSN-155A fission counter. 90% U-235 coating.	Log count rate meter. Period indication metered & recorded.	Light and alarm for excess period.
(d) Octant System (105-C Only)	Uncompensated ion chambers (eight).	Holes in corners of reactor.	6×10^{-15} ampers per nv.	G.E. Mark II. Boron-coated chambers.	Current metered for each chamber. Total current also metered. Twelve-point strip-chart recorder.	None
2. Coolant Flow						
(a) Individual Tube Flow	Venturi with pressure gauge for each process tube.	Inlet to each process tube. Pressure gauge in control room.	Low-trip response to a step change in pressure from mid-scale to ten pounds below low trip is 0.3 seconds or less.	Venturi flow restrictor which develops pressure variation measured by Bourdon-tube type Panellit gauge.	Measurement of pressures in psi.	High and low trips actuate #1 Safety Circuit.
(b) Thermal Shield Coolant Flow	Orifice with pressure gauge.	Inlet to thermal-shield loop header.	Flow through orifice produces differential pressure.	Orifice flow restriction.	Recording of flow in gpm.	None
(c) Reactor Inlet Coolant Flow	Electric signal from power calculator. (See 5a).	Control room.	Electric signal representing total flow.	Output of each power calculator flow channel is summed and fed to a total flow recorder.	Recording of flow in gpm.[b]	None
(d) Horizontal Control Rod Coolant Flow	Orifices with pressure gauges.	Outlet coolant line of each HCR. Also, one orifice and gauge on the "Supply" header for HCR's.	Orifice pressure as a function of flow.	Bourdon-tube type Panellit pressure gauge measuring orifice pressure.	psi	Alarm for each HCR high and low flow. Alarm for HCR supply loss.
(e) Low-Level Neutron Monitor Coolant Flow	Orifices with pressure gauges.	Outlet coolant line of each low-level neutron monitor.	Orifice pressure as a function of flow.	Bourdon-tube type Panellit pressure gauge measuring orifice pressure.	psi	Alarm for water loss.

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System	Description	Location	Sensitivities or Response Characteristics	Design Information	Readout	Alarms or Action
(f) Shutdown Reactor Coolant Flow	Differential pressure gauges (number varies with reactor).	On reactor front face with pressure taps on corresponding front and rear cross headers.	Differential pressure in psi representing flow through process tubes.	Barton differential pressure gauge with over range protection. The process tubes function as orifices.	Differential pressure indicated. Low-trip light for each gauge visible from front elevator.	Alarm in control room and work area for low flow. Used for shutdown flows only.
3. Pressure						
(a) Inlet Header Pressure	Bourdon-tube type pressure gauges, (four to six gauges depending on reactor).	Control room. Sensing line runs to pressure tap on inlet headers.	Direct measure of water pressure in psi.	Taylor or Foxboro, dial-indicating Bourdon gauge.	Pressure in psi indicated.(d)	None
(b) Inlet Riser Pressure	Bourdon-tube type pressure gauges (two or four gauges depending on Reactor).	Control room. Sensing line runs to pressure tap on inlet risers.	Direct measure of water pressure in psi.	Taylor or Foxboro, dial-indicating Bourdon gauge.	Pressure in psi indicated.	None(e)
(c) Inlet Riser Pressure, LP and LLP	Bourdon-tube type pressure gauges (eight).	Electrical-equipment room. Sensing line runs to pressure tap on inlet risers.	Direct measure of water pressure in psi.	Mercoid, type DA-523-3 gauges.	Pressure in psi indicated.	Alarm. Also LP and LLP switches activate #3 Safety Circuit. (See text for details).
(d) Inlet Riser Pressure, ELP	Bourdon-tube type pressure gauges. (four).(c)	Electrical-equipment room. Sensing line runs to pressure tap on inlet risers.	Direct measure of water pressure in psi.	Mercoid, type DA-523-3 gauges.	Pressure in psi indicated.	Alarm. Also actuates #3 Safety Circuit trip.
(e) Thermal Shield Coolant Supply Pressure	Bourdon-tube type pressure gauge.	Control room. Sensing lines run to thermal shield supply header.	Direct measure of water pressure in psi.	Taylor or Foxboro dial-indicating Bourdon gauge.	Pressure in psi indicated.	Alarm only
4. Temperature						
(a) Process Tube Outlet Temperature	Thermocouples	Outlet pigtails of each process tube.	Response times vary from 0.5 to 6 seconds(f).	Copper-Constantan thermocouples fixed in wells. Thermal contact varies in different reactors.	Varies among reactors. Temperatures in °C are sequence-scanned and printed out. Representative tubes can be recorded continuously. Manual patch-board plugging is used to observe any particular tube temperature. Deviation recording of temperatures from 6 - 18 selected tubes.	Alarms off recorders for high temperatures of tubes being recorded.
(b) Process Tube Average Outlet Temperature(g)	Thermocouples	Outlet pigtails of 10-20 selected process tubes.	Response times vary from 0.5 to 6 seconds(f).	Copper-Constantan thermocouples.	Average temperature in °C from selected tubes.	None
(c) Bulk Exit Water Temperature	Resistance Thermal Detectors (RTD).	Varies among reactors. Generally in some part of exit piping.	Fastest response time is 60 seconds for 99% response. For RTD's which are in exit downcomers.	Bristol type 80390-6 RTD or equivalent.	Temperatures in °C recorded.	Alarm for bulk outlet temperature exceeding limit set(h).
(d) Bulk Inlet Water Temperature	RTD's	Inlet headers.	Same as above.	Bristol type 80390-14 RTD or equivalent.	Temperature in °C recorded.	None

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System	Description	Location	Sensitivities or Response Characteristics	Design Information	Readout	Alarms or Action
(e) Zone Temperature Monitor	RTD's (2-3)	Process tube outlet from one tube in every nine.	Response is 1.5 seconds.	Edison RTD. Nickel element in tip.	Temperature measured on dial of Panellit controller. Variable trip setting.	Alarm if temperature exceeds high limit.
(f) Graphite Temperature	Sheathed thermocouples.	Inserted in core in empty process channels.	Range is C - 800 C.	Geminol (P-N) thermocouples in inconel sheaths.	Temperature in °C recorded for each thermocouple.	None
(g) Outlet Coolant Temperatures - HCR's	Thermocouples, RTD's or liquid-filled temperature bulbs depending on reactor.	Outlet coolant at HCR.	Range is 0 - 100 C to 0 - 150 C.	Taylor temperature bulbs, Copper-Constantan thermocouples or Brown, type A, nickel RTD's.	Degrees C indicated by various types of gauges and meters.	None
5 Power						
(a) Power Calculator	Combines flow and ΔT measurements to derive power. 1) Venturi with ΔP transmitter 2) RTD's 3) Orifice and ΔP transmitter.	Devices located as follows: 1) Inlet headers, near and far sides of reactor. 2) Inlet headers and bottom of exit downcomers. 3) Inlet to thermal shield coolant.	RTD's response time is estimated at 60 seconds for 99% response.	ΔP transmitters are Foxboro, type 28, mercury manometers. RTD's are Foxboro Type M-7060-L, nickel elements. Risistance at 0 C is 235 ohms.	Total power recorded in Mw and total flow in gpm. Power deviation between ± 50 Mw also recorded.	None
(b) Power Rate-of-Rise	Stop-gap system employing RTD's.	RTD's located on selected process tube outlets.	Response time is 1.5 seconds.	Edison, ickel RTD. Resistance at 0C is 90 ohms.	Power-rate meter.	None
6. Miscellaneous						
(a) Seismoscope	Pendulum-type seismoscope starters. (three)	Electrical equipment room.	0.9 second period. Damping ratio of 9 to 1. One seismoscope set at MM2. Two at MM5.	O.S. Peters seismoscope starters.	Electrical contact closed when pendulum swings.	MM2 seismoscope trip annunciated. Both MM5 seismoscopes must trip to cause #1 Safety Circuit action.
(b) Power Failure	Power failure sensing relays.	Power circuits in 190 Buildings, on process pumps. 8 - 10 relays in each area.	800 kw dropout point, which is 20-23% of normal power load.	G.E. type CFW, over-under power relays.	None	Alarm plus trip of #1 Safety Circuit. Backup pumps are also started by power-failure trip.

(a) Except at C Reactor where summed durrent from eight chambers of octant system is used.
(b) At C Reactor, combined A-bank and B-bank flow is also recorded.
(c) H Reactor has no ELP gauge.
(d) Inlet header pressure is also recorded at B, D, and F Reactors.
(e) Except at C Reactor where low inlet riser pressure is annunciated.
(f) Older type thermocouples at H and DR Reactors may have response times longer than six seconds.
(g) Twelve-tube average temperature monitor at H Reactor temporarily disconnected until thermocouple replacement program is completed.
(h) No alarm at C Reactor for high bulk outlet temperature.

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SUMMARY OF BYPASS SWITCH CONTROLS

Name or System	Method and Location	Method of Communicating Status	Conditions for Use	Backup
1. Beckman No.1 (Beckman's No. 2,3, and 4 are same as No. 1) Flux Monitor.	Manual key-locked switch in 105 control room.	Audible alarm. Indicating light. Start-up check.	Range changing or maintenance work, one instrument at a time. During outage, all Beckmans may be removed from service for maintenance provided that the trips are open and un-bypassed and back-up instruments are in service and observed.	Remaining three Beckmans. Sub-critical monitors during an outage. Bypassing more than one at a time will trip #1 Safety Circuit.
2. Seismoscope	Manual key-locked switch in 105 control room.	Audible alarm. Indicating light. Start-up check.	During reactor outages. Also short periods for test or repair.	Manual action upon seismoscope alarms.
3. Water Pressure Trip of Ball 3X System, LP & VLP	Manual key-locked switch in 105 control room.	Audible alarm. Indicating light. Start-up check.	After reactor is shut down and before water pressure is decreased.	Manual trip. ELP pressure switch trip, if un-bypassed and lock bars removed.
4. Water Pressure Trip of Ball 3X System, ELP	Manual key-locked switch in 105 control room.	Indicating light. Procedure and startup check.	Un-bypassed in event of evacuation.	Manual trip of Ball 3X System.
5. Ball 3X Lock Bars.	Manual insertion of locking-bars on ball 3X hoppers, 105 Building.	Indicating light in control room for each hopper door and test gate. Startup checks. Light is not selective for door and test gate.	Reactor outage only and under the conditions and limits specified by reactor physicist.	Manual removal of locking bars. Vertical safety rods and/or supplementary control must be inserted to compensate.

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Name or System	Method and Location	Method of Communicating Status	Conditions for Use	Backup
6. SN Relay, (VSR Upper Limit Switches	Manual key-locked switch in 105 control room.	Audible alarms. Indicating light. Procedure and startup check.	Reactor outage. Permits HCR removal when all VSR's are not up.	Manual trip.
7. HCR Bypass and VSR Trip.	Manual key-locked switch in 105 control room.	Audible alarm. Indicating light.	VSR drop without insertion of HCR or in case of rod water loss. Permit HCR movement during reactor outage without VSR movement. VSR-HCR interlock trips No. 1 Safety Circuit when SN relay is bypassed.	Manual trip.
8. HCR Outer Limit Switch.	Manual switch in 105 control room.	Audible alarm. Indicating light.	Permits only HCR to be fully withdrawn.	If HCR is withdrawn during reactor operation, the rod strength is replaced with splines or poison.
9. HCR Deadman Switch.	Manual key-locked switch in 105 control room.	Alarm and Indicating light. Procedures.	Switch is normally in bypass position except when bulk outlet temperature is above predetermined limit. When in un-bypassed position, withdrawal limited to 12 inches without circuit reset.	Automatically unbypassed by interlock with bulk outlet temperature.

	Name or System	Method and Location	Method of Communicating Status	Conditions For Use	Backup
10.	PCCF, Individual Tube Bypass of Panellit Pressure Monitor.	Manual key-locked switch in 105 control room.	Indicating light. Procedure.	To remove a PCCF tube Panellit gauge from #1 Safety Circuit in order to charge or discharge non-fissionable material during reactor operation. Observation of Panellit during charging.	Manual trip if pressure is abnormal.
11.	Bulk Outlet - PCCF Interlock	Manual key-locked switch in 105 control room.	Indicating light and audible alarm.	Bypassing permitted for specified bulk outlet temperatures and column poison value.	Procedural control for discharge above a specified bulk limit.
12.	PCCF Time Delay Relay	Manual key-locked switch in 105 control room.	Indicating light. Audible alarm. Procedure.	Bypass the instant PCCF trip and put in a two-minute time delay before trip.	If alarm is corrected in two minutes, no trip is performed.
13.	Zone Temperature Monitor.	Manual key-locked switch in 105 control room.	Audible alarm. Indicating light.	Contacts in No. 1 Safety Circuit bypassed until present false scram rate is reduced by equipment improvement.	Corrective action taken upon high limit alarm. Startup not permitted with more than 10 RTD's out of service.
14.	Zone Temperature Monitor, Individual tubes.	Plug-in jumper wire.	Procedure. Log book.	Repair of individual tube module	Plug-in of spare amplifier. Thermocouple temperature measurement.
15.	Low-Level Neutron Monitor, (Sub-Critical Monitor).	Manual key-locked switch in control room.	Procedure. Indicating lights.	Continuous bypass of period trip in No. 1 Safety Circuit.	Manual trip.

Name or System	Method and Location	Method of Communicating Status	Conditions For Use	Backup
16. Beckman - Safety Circuit Interlock.	Relay contacts operated through logic by Beckman flux monitors.	Procedure indicating lights.	No. 1 Safety Circuit cannot be reset until at least three Beckmans are on low range.	Procedure.
17. Panellit Pressure Monitor.	Manual key-locked switch in 105 control room. Automatically un-bypassed by relay	Audible alarm. Indicating light. Startup checks.	During reactor operation at low level, below 2 Mw, Panellit system may be bypassed.	Beckman - Panellit interlock automatically un-bypassed Panellit pressure monitor above 2 Mw.
18. Panellit Gauge	Plug-in jumper wire.	Procedure.	Repair of Panellit gauge or replace. Allow up to two hours to be bypassed. visual observations required while bypassed.	Tube outlet temperature monitor. Manual trip.
19. Power Loss Relays (190 Pumps)	Manual key-locked switches in 190 control room for	Audible alarm. Indicating light. Procedure and log book.		Automatic start of turbines on pressure decrease.
20. Riser Pressure Mercoids.	Manual key-locked switch in 190 control room.	Audible alarm. Indicating light. Procedure and log book. Startup check.		Master turbine control or manual operation.

Name or System	Method and Location	Method of Communicating Status	Conditions For Use	Backup
21. Master Turbine Control	Manual key-locked switch in 190 control room.	Procedure and log-books. Startup check. Annunciator and indicating light for each turbine.	During reactor outage. In bypassed position, the controls automatically regulate riser at shut-down pressures. Normal.	Manual control.
22. Master Pumping control, Cone Valves.	Manual switch in 190 control room	Procedure, log books and startup checks. Indicating light for valve action.	Valves opened for flow to reactor during operation and closed during outage.	Manual control of each core valve.
23. Emergency Turbine Control Valve	Manual switch in 183 pump room	Procedure, log book, and startup checks.	Bypassed only for repairs.	Manual operation of two backup turbines.
24. Groves Valve Impulse Bleed	Manual shutoff of bleed and insertion of locking pins, 105 valve pit.	Procedure.		Manual unlocking.
25. Emergency Generator	Manual switch, 184 Building.	Annunciator and indicating light. Procedure and log book.		
26. Master Steam Control	Manual switch in 184 control room.	Procedure and log book. Startup checks.	Bypass shifts control to individual boilers.	Manual operation.

Name or System	Method and Location	Method of Communicating Status	Conditions For Use	Backup
27. Boiler Panel Control	Manual switch in 184 Building.	Procedure and log books. Startup checks.	Bypass for boiler shut-down and repair	Manual operation.
28. Main Cross-Tie Valves, A & B Risers	Manual switch in 190 control room.	Procedure. Indicating lights show open or closed.	During reactor operation the cross-tie valve is closed. Open during reactor outage.	Reactor backup water supply system.
29. Water Pressure Switch, VLP.	Automatic operation by time delay relay in electrical equipment room initiated by LP pressure switch.	Automatic operation.	Bypassing is automatically performed if water pressure decay rate is slow enough.	Trip of No. 3 Safety Circuit.

IX. FUEL

A. Description of Fuel Elements

The fuel for the B, D, DR, F and H Reactors is predominantly natural uranium. To provide excess reactivity and power flattening, enriched uranium fuel (0.947 w % U-235) is also used. The fuel geometry is tubular, enabling coolant to flow within the fuel as well as outside of it. The cladding is X-8001 aluminum alloy bonded to the uranium by a layer of eutectic aluminum-silicon alloy. The tubular fuel element has been in service for about five years, replacing the original solid cylindrical Hanford fuel element.

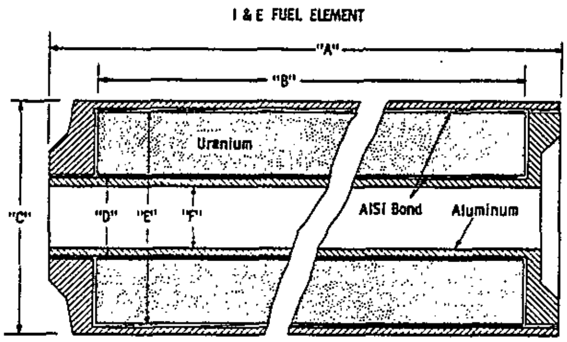
The fuel elements used in smooth-bore, Zircaloy-2 process tubes differ from those used in ribbed aluminum process tubes in that they are slightly larger and that the fuel positioning is accomplished by supports attached to the fuel element. In ribbed process tubes the fuel is supported on the tube ribs which extend the full length of the process tube. The dimensions and types of fuel elements now in use are shown in Figure IX-1.

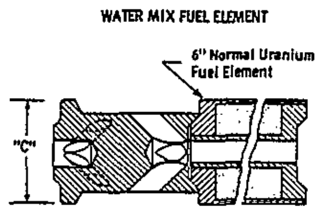
Spacers of aluminum are used to position the fuel charge within the active zone of the reactor. These spacers are tubular with either perforated or solid walls. They are generally eight inches in length, although some five inch perforated spacers are utilized. To prevent obstruction of flow, perforated spacers are used adjacent to the fuel charge and in the rear nozzle. The spacers used in smooth tubes have extruded ribs the full length of the piece.

B. Pre-Irradiation Handling

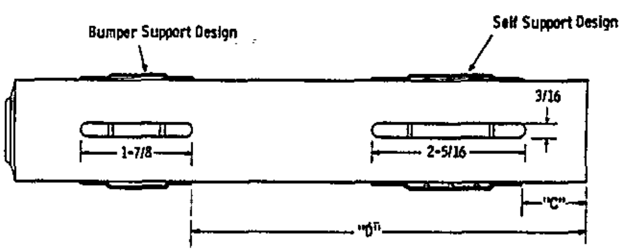
Fuel elements are normally shipped by truck from the fuel manufacturing plant to the reactors in shipping pallets, with provisions for either 200 or 300 fuel elements. The fuel elements are usually stored in the shipping pallets, but may be placed in charge boxes for convenience several days prior to their actual use. There are no nuclear restrictions limiting the storage of natural uranium. The shipping pallets or charge boxes may be stacked as high and as close to other pallets or charge boxes as practical. Enriched uranium elements (0.947 weight percent U-235), however, have definite storage limitations to preclude accidental criticality. The storage of natural and enriched fuel elements together requires the use of the enriched uranium storage restrictions for those elements involved. The storage of enriches elements in the shipping pallets is restricted to rows three pallets high with twelve inches of free space between rows. The stacks of pallets of enriched fuel elements are required to be placed at least six feet from the stacks of natural uranium elements. Storage of enriched elements in charge boxes is limited to a single layer of boxes without regard to spacing between the boxes. Secured storage for enriched metal is provided at each reactor. Standards for the storage of more highly enriched fuels are available if needed.

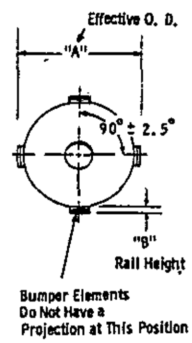
Fuel elements are transferred from the shipping pallets to charge boxes by hand, and moved by portable carts, hoists, and conveyors to the charging machines.





Dimension	Normal Uranium							0.947 % Enriched Uranium				Normal Uranium Watermix		
	C II N	C V N	C VI N	K IV N	K V N	O III N	O V N	C III E	K IV E	K V E	O III E	C III W	K IV W	O III W
A +0.120" -0.080"	8.965"	8.965"	8.865"	8.965"	8.865"	8.965"	4.665"	6.640"	6.640"	6.540"	6.640"	6.640"	6.640"	6.640"
B ±0.010"	8.378"	8.378"	8.325"	8.378"	8.325"	8.378"	4.078"	6.053"	6.053"	6.000"	6.053"	6.053"	6.053"	6.053"
C ±0.006"	1.466"	1.494"	1.986"	1.460"	1.520"	1.444"	1.443"	1.460"	1.459"	1.509"	1.443"	1.460"	1.459"	1.443"
D 1 ±0.007" 2 ±0.004"	0.481"[1]	0.488"[2]	0.452"[2]	0.498"[2]	0.533"[2]	0.423"[2]	0.423"[2]	0.488"[2]	0.513"[2]	0.545"[2]	0.423"[2]	0.488"[2]	0.513"[2]	0.423"[2]
E +0.001" -0.002"	1.370"	1.406"	1.883"	1.370"	1.431"	1.356"	1.356"	1.370"	1.370"	1.419"	1.356"	1.370"	1.370"	1.356"
F ±0.006"	0.375"	0.375"	0.334"	0.385"	0.420"	0.310"	0.310"	0.375"	0.400"	0.432"	0.310"	0.375"	0.400"	0.310"
Nominal Can Wall Thickness Before Canning	0.040"	0.037"	0.045"	0.037"	0.037"	0.037"	0.037"	0.037"	0.037"	0.037"	0.037"	0.037"	0.037"	0.037"
Nominal Spire Wall Thickness Before Canning	0.045"	0.050"	0.050"	0.050"	0.050"	0.050"	0.050"	0.050"	0.050"	0.050"	0.050"	0.050"	0.050"	0.050"
Canned Factor Weight, Pounds	7.37	7.78	14.87	7.29	7.86	7.43	3.60	5.29	5.21	5.49	5.36	5.29	5.21	5.36





Dimension	I & E Self Supporting Fuel Element			I & E Bumper Fuel Element	
	C V N	C VI N	K V N	O III N	O III E
A ±0.006	1.666	2.130	1.710	1.530	1.530
B ±0.003	0.082	0.069	0.095	0.040	0.040
C ±0.03	1.25	1.25	1.25	1.50	0.56
D ±0.03	5.25	5.25	5.25	5.44	4.06

FIGURE IX-1
Fuel Element Dimensions

C. Reactor Refueling Procedure

The normal method of refueling is displacement charge-discharge during a reactor shutdown. This procedure is simply illustrated in Figure IX-2. The charging machines are located on the front work platforms and are either manually or automatically operated. These machines require an air supply of approximately 100 psi, and use the reactor building air supply.

During a charge-discharge operation, the tubes to be discharged have the rear nozzle caps removed. All personnel are then evacuated from the rear work platform and the platform is raised to the top of the unit. Electrical interlocks prevent operation of the charging equipment on the front work platform until the rear work platform is raised to the top limit of travel and all rear entry ways closed.

The front face activities for charging consist of transferring the loaded charge boxes from the work area floor to the charge work platform. The inlet nozzle cap of the process tube is removed and the desired number of aluminum spacers are inserted into the tube by hand. The charging machine is then connected to the process tube nozzle. The fuel elements are removed by hand from the charge box and placed on a gravity feed tray on the charging machine. The fuel elements are pushed into the process tube by the machine causing the displacement of the irradiated fuel elements in the tube, and discharging into the discharge basin.

D. Post-Irradiation Handling

Post-irradiation handling of the natural uranium fuel elements presents no criticality problems. The discharged irradiated elements drop into a water filled discharge chute and slide down into the metal pickup area at the end of the storage basin. The water in the storage basin is about twenty feet deep and provides ample radiation shielding for personnel. The natural uranium elements are generally allowed to accumulate in the discharge chutes until the end of the refueling procedure, at which time they are transferred to storage buckets by means of long pickup tongs. The loaded buckets, each of which holds about 250 fuel elements, are moved by means of electric hoists and a monorail system. There are no restrictions in the storage of irradiated natural uranium. Shipment of the irradiated elements from the reactors to the separations plants is by rail in a cask car with no restrictions, other than those imposed by the physical system, on the number of natural elements to be loaded or shipped in a cask.

There are definite restrictions imposed in handling, storing and shipping of irradiated, enriched-uranium, fuel elements. First, the maximum number of irradiated enriched fuel elements permitted in a discharge chute is as follows:

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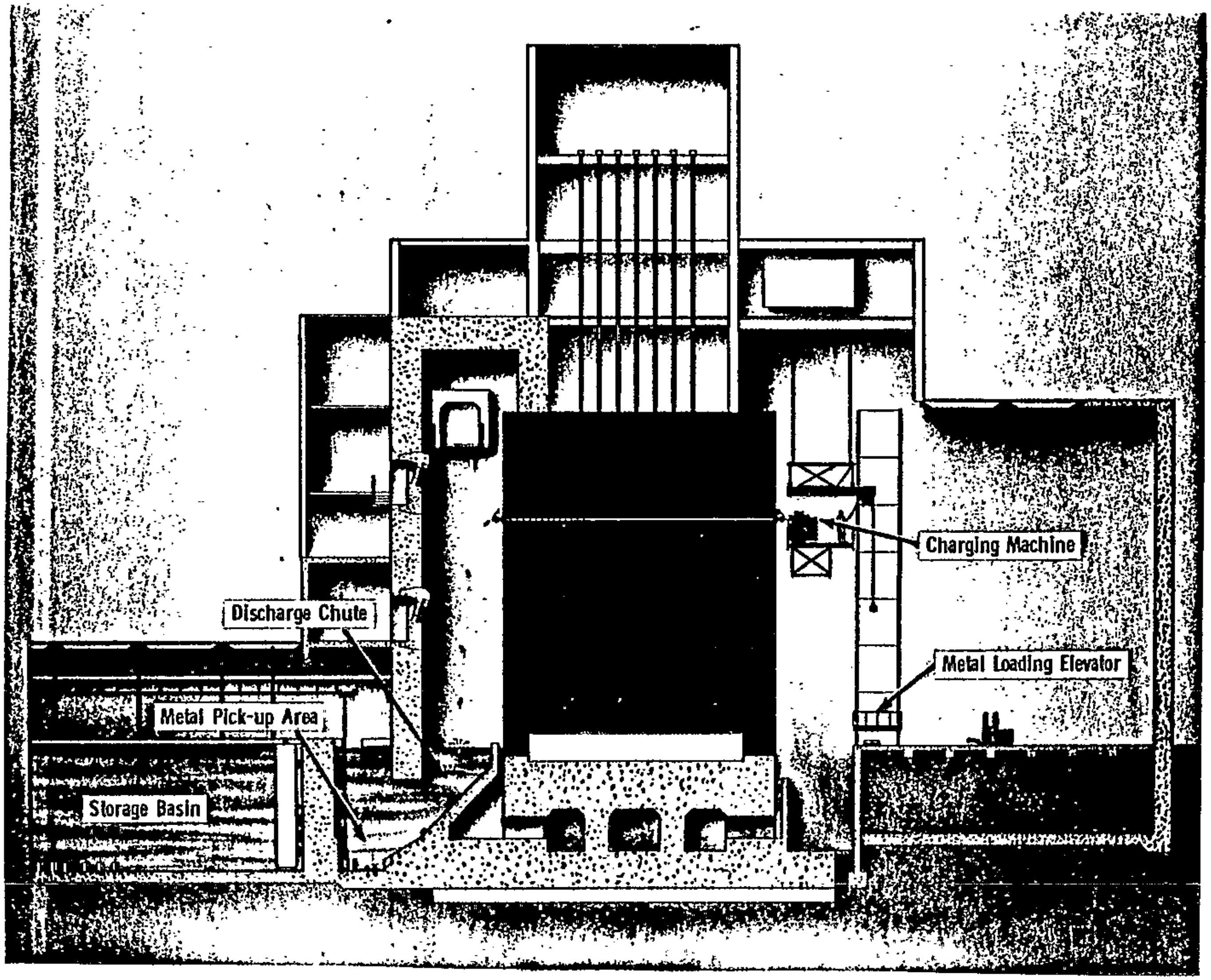

FIGURE IX-2

Reactor Charge-Discharge

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Enriched fuel elements only - 0 to 800 fuel elements

Enriched fuel elements plus natural fuel elements -
1) 0 to 300 enriched fuel elements plus unlimited quantities of natural fuel elements
2) 301 to 800 enriched fuel elements with the total of enriched and natural fuel elements not to exceed 800.

To prevent these restrictions from severely limiting refueling rates, the enriched fuel elements can be allowed to fall directly into buckets in a random fashion and stored in specially designated storage positions for sorting at a more convenient time.

The storage of filled buckets of enriched fuel elements is limited to a single layer and a single row. Restrictions on the shipment of enriched fuel elements in the cask cars are detailed and depend upon the percentage of U-235 by weight, the length and degree of exposure of the fuel elements and whether the shipment is to be made in a water-cooled well car or in an air cooled cask.

E. Fuel Failure Detection

The detection of fuel element failures is accomplished by monitoring process tube flow rate and effluent radioactivity. The process tube flow is monitored by the Panellit system which registers the throat pressure of the individual process tube flow meters and is described in more detail in Section VIII - Reactor Instrumentation. The process water effluent radioactivity is measured by the Gamma Monitoring System which continuously samples effluent water from each end of each outlet crossheader. Visual and audible alarms are located in the control room.

X. REACTOR CONFINEMENT

A. General

Confinement facilities were installed in the reactor buildings in 1960 to control the release of radioactive matter from the reactor buildings in the event of a nuclear incident. The method of control is to confine the flow of the ventilation air in the building to a definite path, and to exhaust it through filters before release from the exhaust stack. This control was achieved by using two design principles. The confinement zone in the reactor building is maintained at pressures slightly less than atmospheric, and the exhaust equipment is designed for the maximum feasible degree of reliability. Figures X-1 and X-2 illustrate confinement of the ventilation air.

The confinement zone in the 105 Building is defined as those ventilated spaces in the building adjacent to the reactor block. These spaces are the rear face enclosure (discharge area), the work area, the top of reactor, the X-levels, the inner rod room, and the exhaust tunnel leading to the exhaust fans. To assist in maintaining the slightly negative pressures within the zone, doors are installed in all openings leading into these building spaces and are kept closed except for normal work access. A slightly negative air flow through the zone is obtained by closing the openings in the zone boundaries and reducing the supply of ventilation air to the zone. Air flow outside of the confinement zone is inward to the zone, thereby confining the spread of contamination within the zone.

B. Fog Spray System

The fog spray system is located within the rear face enclosure and produces a finely divided spray of water for absorbing a portion of the halogen vapors released during an uranium fire, settling out a portion of the airborne particulate matter released during fuel element fires, washing down exposed surfaces within the rear face enclosure for the removal of contaminated particles providing some degree of thermal cooling to exposed fuel elements, and condensing any steam that may be formed, to prevent unnecessary pressure buildup within this area. Figure X-3 shows the arrangement of the system.

The fog spray piping is made up of the water supply pipe, a control valve, and a spray nozzle manifold. Spray concentration is equal to approximately two inches of rainfall per five minutes

The fog spray system is supplied from the 105 Building filtered water loop in the discharged fuel storage area. The automatic control valve station for the system is located immediately after the point the supply piping connects to this loop. The valve station consists of a solenoid operated control valve, and a bypass containing a gate valve. The bypass valve is for manual control. An air operated butterfly valve is installed in the 8-inch basin fill line, which is also supplied by the filtered water loop. The automatic control valve and the butterfly valve are interlocked so that when the control valve opens

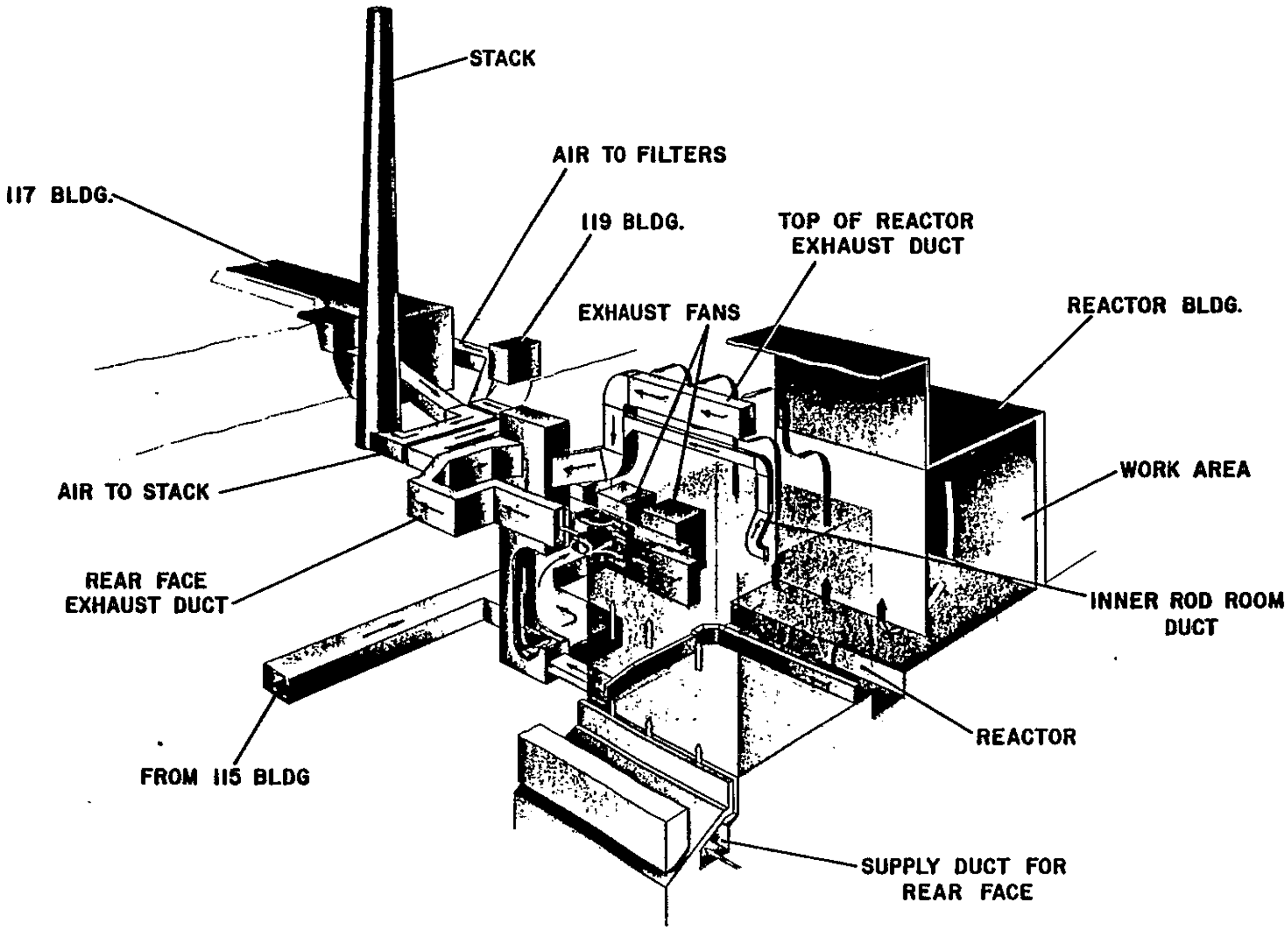

FIGURE X-1

Confinement Facility Layout, B, D, and F Reactors

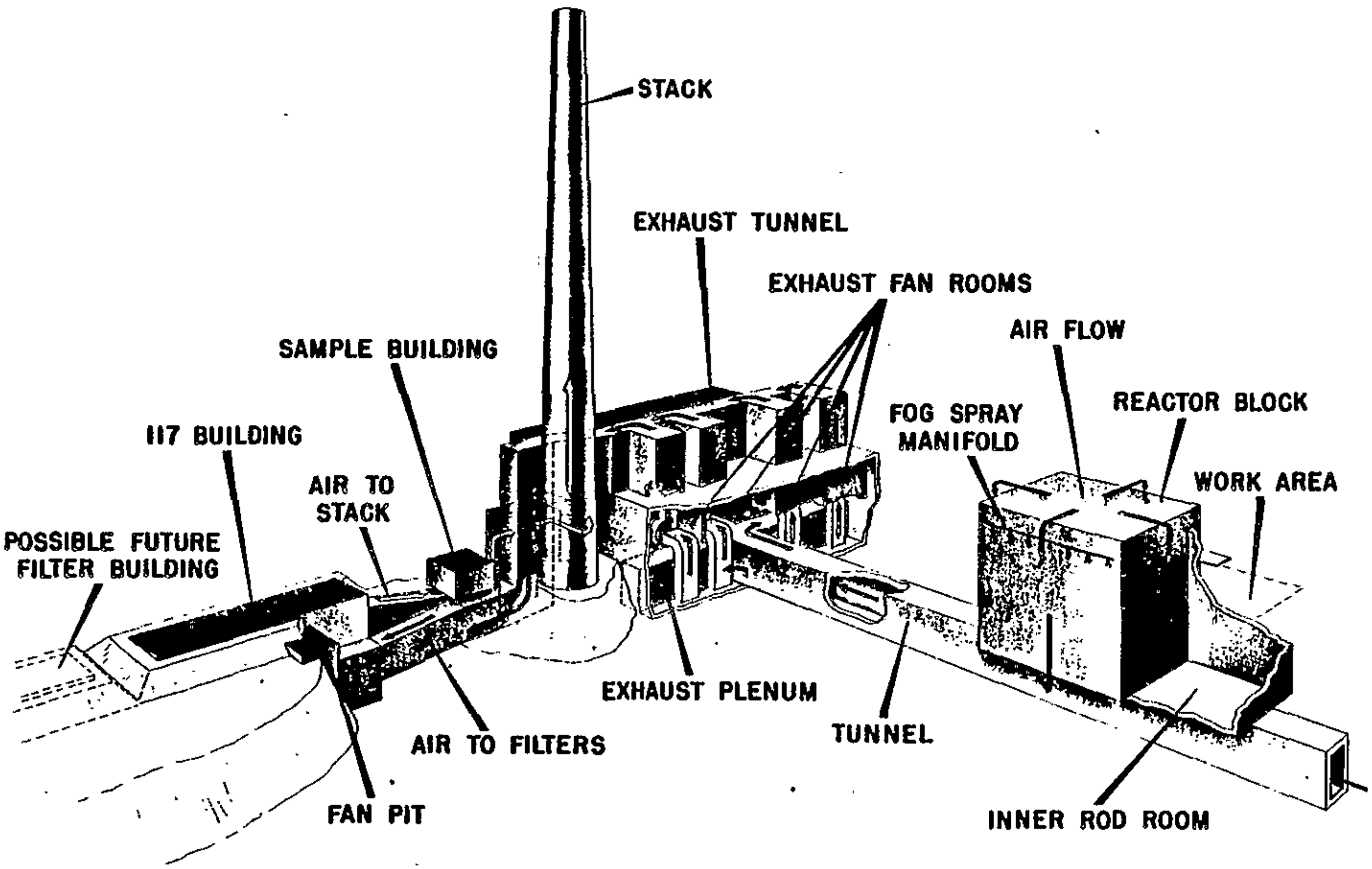

FIGURE X-2
Confinement Facility Layout, C Reactor

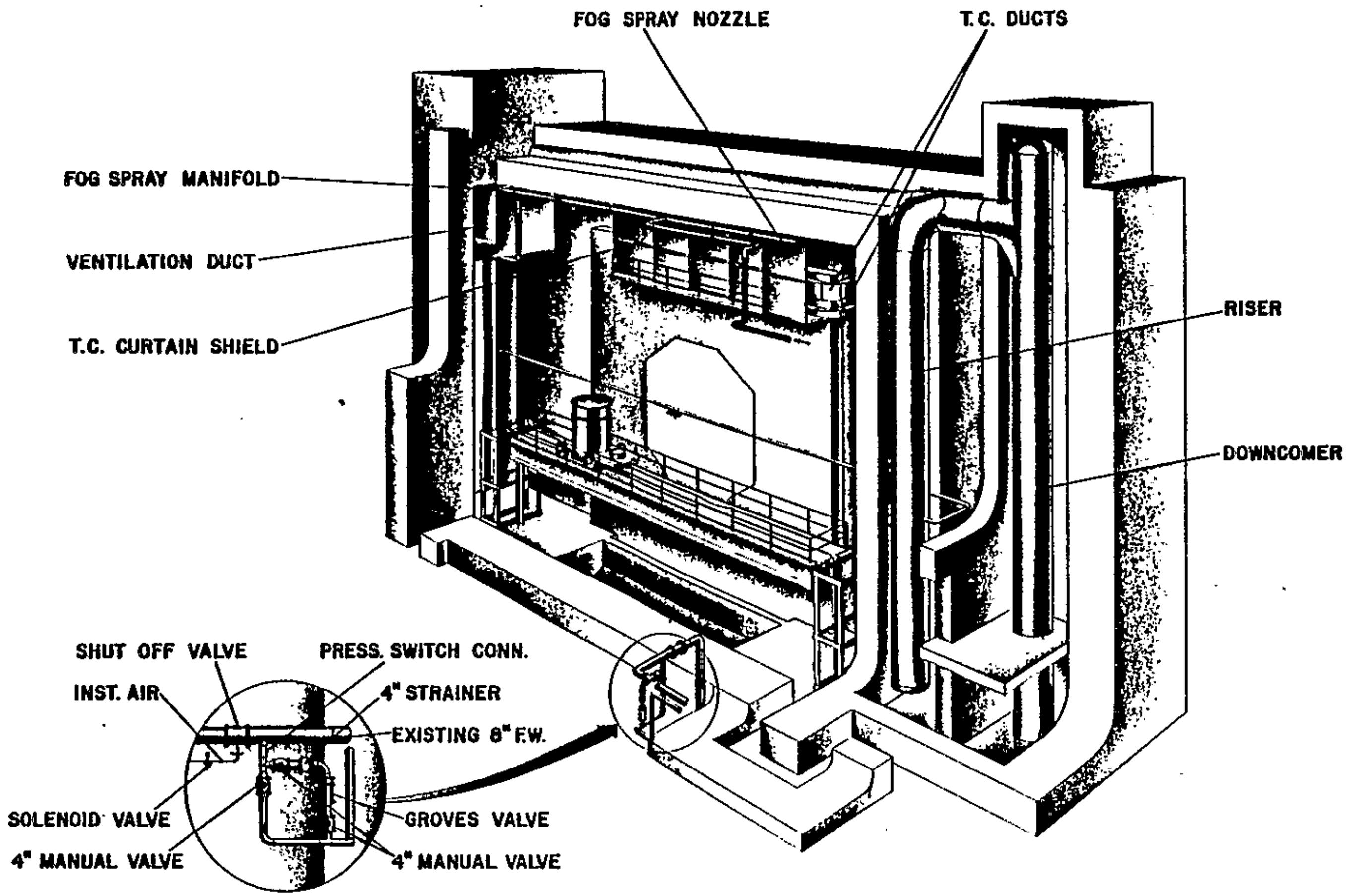

FIGURE X-3

Typical Fog Spray System

the butterfly valve closes and vice versa. The butterfly valve is needed to ensure that the fog spray system will not lose water supply when the discharge basin fill line is open.

After the valve station, the water supply pipe extends to the ceiling of the rear face enclosure and connects into the spray nozzle header which has a one-inch, low-pressure spray nozzles mounted at ten-foot intervals. The fog spray piping and header is 4-inch, Schedule 40, stainless steel pipe. The supply pipe is of welded construction, and the header is assembled from flanged sections.

The fog spray system is automatically controlled by a scintillation detector system which continuously monitors the reactor building exhaust air and actuates the system whenever the presence of radio-iodine is detected in the exhaust air stream. The spray system can also be manually actuated from the control room and from the viewing windows in the rear face enclosure.

When the fog spray control is on automatic operation, the system cannot be actuated unless all of the rear face doors are closed. This condition can be overridden by an emergency switch located in the 105 Building Control Room.

C. Ventilation and Exhaust System

Figure X-4 is a simplified flow chart of the 105 Building ventilation and exhaust system. Air is supplied to the building by two separate supply systems. These supply systems condition the air and distribute it to a particular section of the building. The ventilation air supplied to the building spaces outside of the confinement zone is exhausted to the atmosphere through roof ventilators. Air supplied to spaces in the confinement zone is collected by exhaust ducts which discharge into the exhaust tunnel.

Movement of air in the confinement zones is as follows: Air supplied to the work area flows toward the reactor front face, sweeps up the face and over the top of the reactor to the exhaust duct located on the far side of the reactor. Air is supplied to the Inner-rod Room through the Outer-rod Room, and is exhausted in the B, D, F, and DR Reactors, into a duct which runs over the reactor and connects into a common exhaust duct on the far side. In the C and H Reactors, air from the Inner-rod Room is exhausted directly to exhaust tunnel.

Supply air to the rear face enclosure in the B, D, DR, and F Reactors comes in at the base of the reactor, sweeps up the reactor rear face, and is exhausted to the common duct on the far side. At the C and H Reactors, the rear face air flow is reversed, coming in at the top and exhausting into the main exhaust tunnel beneath the reactor.

The air in the exhaust tunnel then flows to the exhaust fans. At the B, D, and F Reactors, contaminated air from the 115 Building is also exhausted to the main exhaust tunnel through the underground gas piping tunnel which connects to the main exhaust tunnel at the far side of the reactor.

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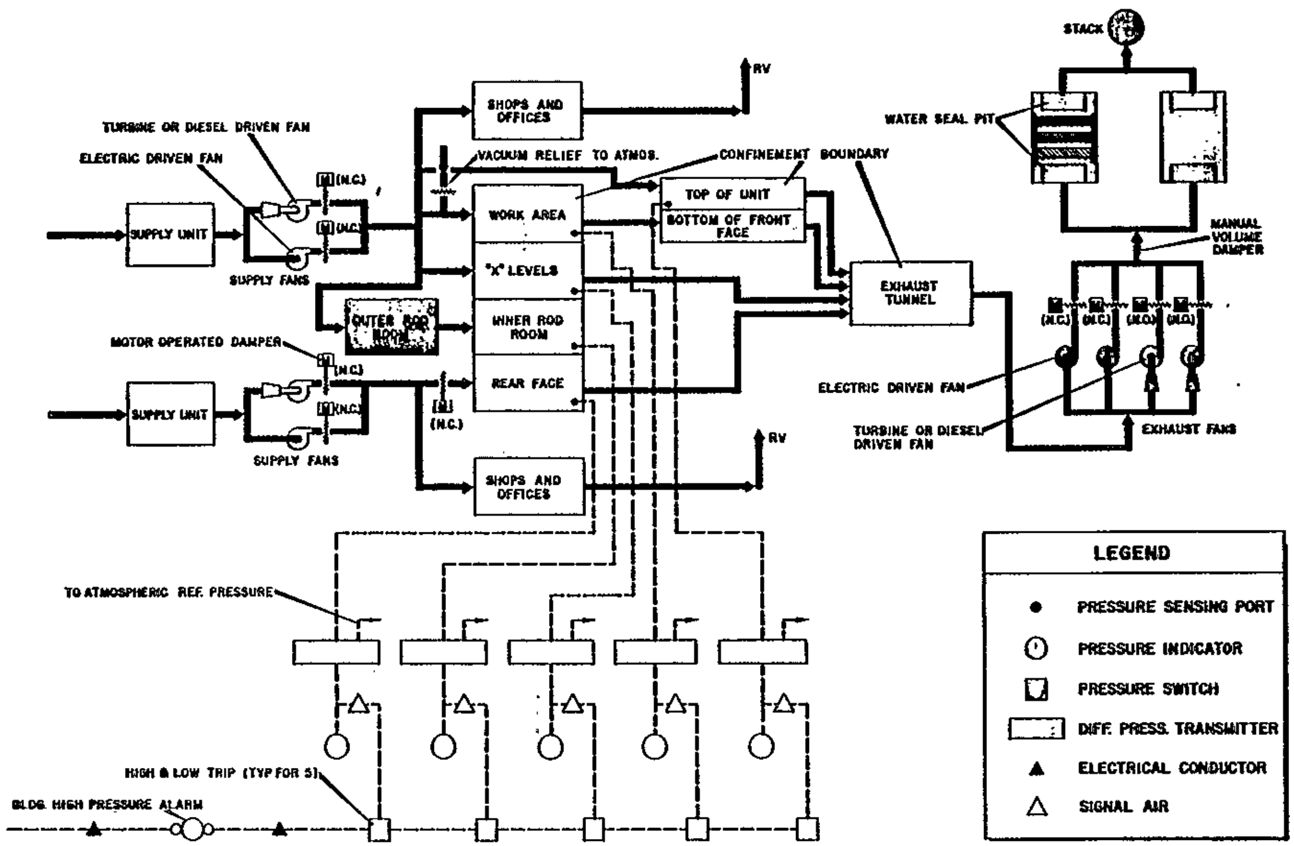

FIGURE X-4

Reactor Confinement Flow Diagram

At the exhaust fans, the exhaust air becomes pressurized and is exhausted through an aboveground concrete duct which runs to the base of the 200-foot exhaust stack. At the base of the stack, the exhaust flow is diverted into an underground reinforced concrete duct which leads to the filter building. After passing through the filters, the air flows back through an underground reinforced concrete duct, is diverted back into the aboveground concrete duct to the exhaust stack from which it is exhausted to the atmosphere.

The nominal flow capacity of the exhaust system of the different reactors is:

Reactor	Flow, cfm
B, D, F	100,000
DR	85,000
C	135,000
H	160,000

Approximately eighty percent of the exhaust air is supplied directly to the confinement zone by the ventilation supply systems of the building. The other twenty percent is air which has infiltrated into the confinement zone.

Four, identical, non-overloading, Class II, centrifugal fans are provided in the ventilation supply system of the reactor buildings. Two are electric-driven, V-belt connected; and two are steam-driven, direct connected. The electric fans are normally operated with the steam-driven fans for standby. Air-operated, normally-closed dampers are provided on the discharge of all fans to close the supply ducts to the building whenever the fans are not operating. All supply fans are manually started.

The fans in the exhaust system are non-overloading, Class III and IV, centrifugal fans. Four identical fans are provided in the exhaust system: two electric-driven, V-belt connected; and two steam-driven, direct connected. Each fan is located in a separate fan room. Air-operated discharge dampers are installed on the fans and are normally closed on the electric-driven fans, and normally open on the steam-driven fans.

The electric fans are normally operated with the steam fans on standby. These fans are intertied with their backup steam-driven fan so that when electric power is lost the steam-driven fans automatically start, the discharge dampers of the electric fans close, and the dampers on the steam fans open. The electric fans are manually started and the steam fans manually shut-off.

Ratings of the exhaust fans of the different reactor buildings are:

Reactor Building	Flow, cfm	Exhaust Fan Head, inches	Electric Drive hp	Steam Drive hp
B, D, F	50,000	10-1/2	150	150
DR	42,500	11	125	100
C	75,000	11	200	191
H	75,000	11	200	179

Other features of the ventilation and exhaust systems are: a manually-operated flow control damper installed in exhaust duct downstream of the exhaust fans for regulating the flow of the exhaust system; a vacuum relief damper installed in one of the supply ducts to open to atmosphere if negative pressure in the reactor building exceeds 2-inches water gage; an air-operated damper in the supply duct to the rear face enclosure to close to ten percent to restrict flow to the rear face during an incident, thereby providing longer scrubbing time of the air with the fog spray system.

D. Exhaust Air Filters - 117 Building

The exhaust air filter building is a reinforced concrete structure located almost entirely below grade and is shown schematically in Figures X-5, X-6 and X-7. The underground installation was utilized because the earth is inexpensive shielding ; the building and associated ductwork would be less hindrance to movement of vehicles and personnel within the area; and abandonment, in place, would be much simpler, should this ever become necessary.

The filter building is approximately fifty-nine feet long, thirty-nine feet wide, and thirty-five feet high. It is connected to the 105 Building exhaust air system by two underground concrete ducts. These ducts extend along the length of the filter building and serve as the intake and exhaust plenums to the filter cells. Adjacent to the filter cells, the lower 84-inches of the duct is provided with turning vanes to deflect the air into or out of the filter cell. This lower section of the duct also serves as a portion of the seal-pit for isolating the filter cells.

The building is divided into two identical filter cells with a two-storied operating gallery between the cells. The upper floor provides access to the cells and ducts, while the lower contains the seal-pit pump, the fill and drain lines, and the ductwork of the small exhaust system in the filter building. Access to the cells or the exhaust and supply ducts is through metal doors. Three accesses are provided to each cell and one access is provided to the exhaust and supply ducts, respectively.

Inside each cell are slots for three filter banks, which are subdivided into two sections in which 9-foot wide, approximately, aluminum filter frames are installed. These frames are installed remotely through an opening in the top of the cell (see Figure X-8). The frame is lowered by a mobile crane into a

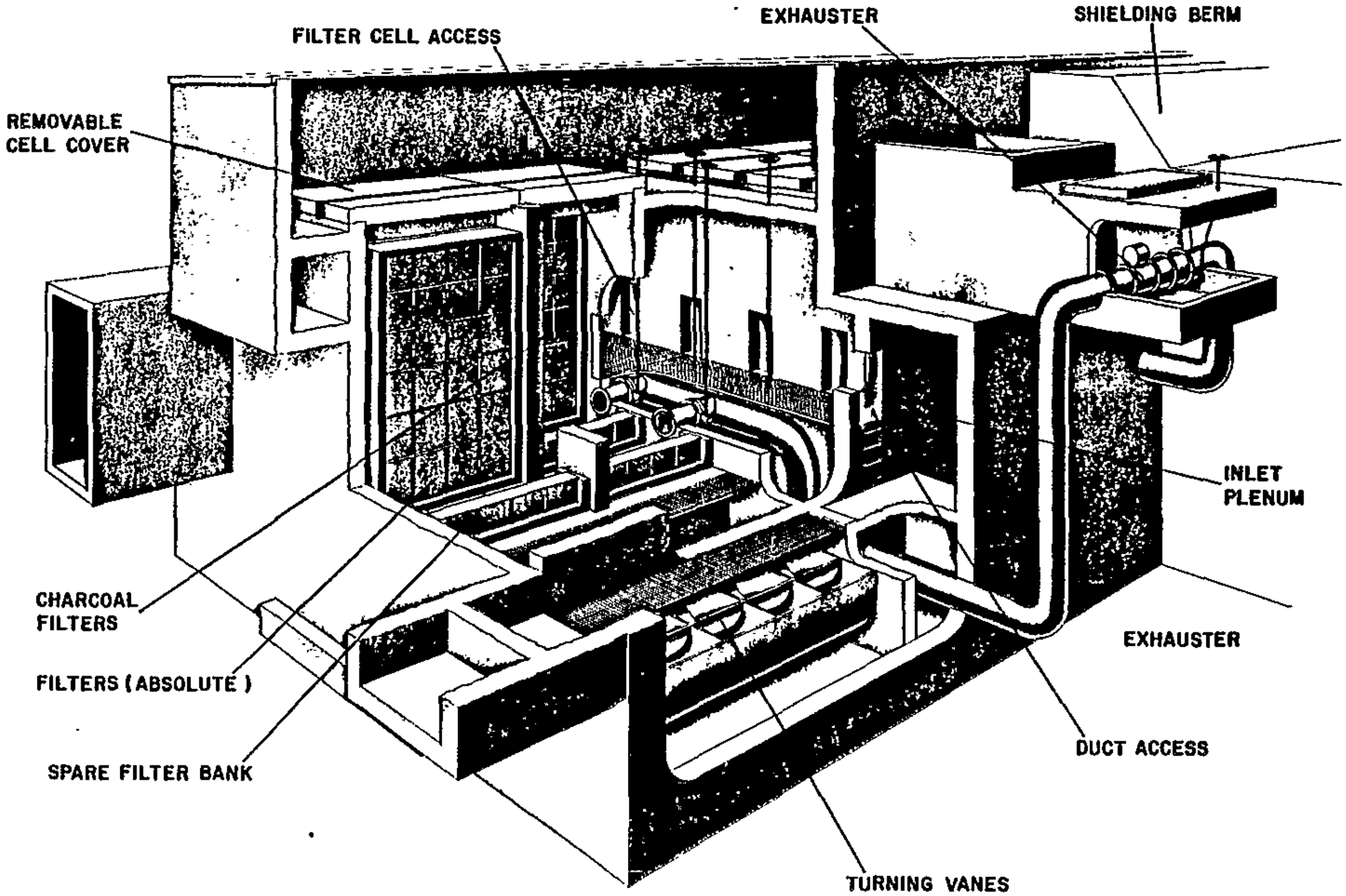

FIGURE X-5
Reactor Confinement Filter Building

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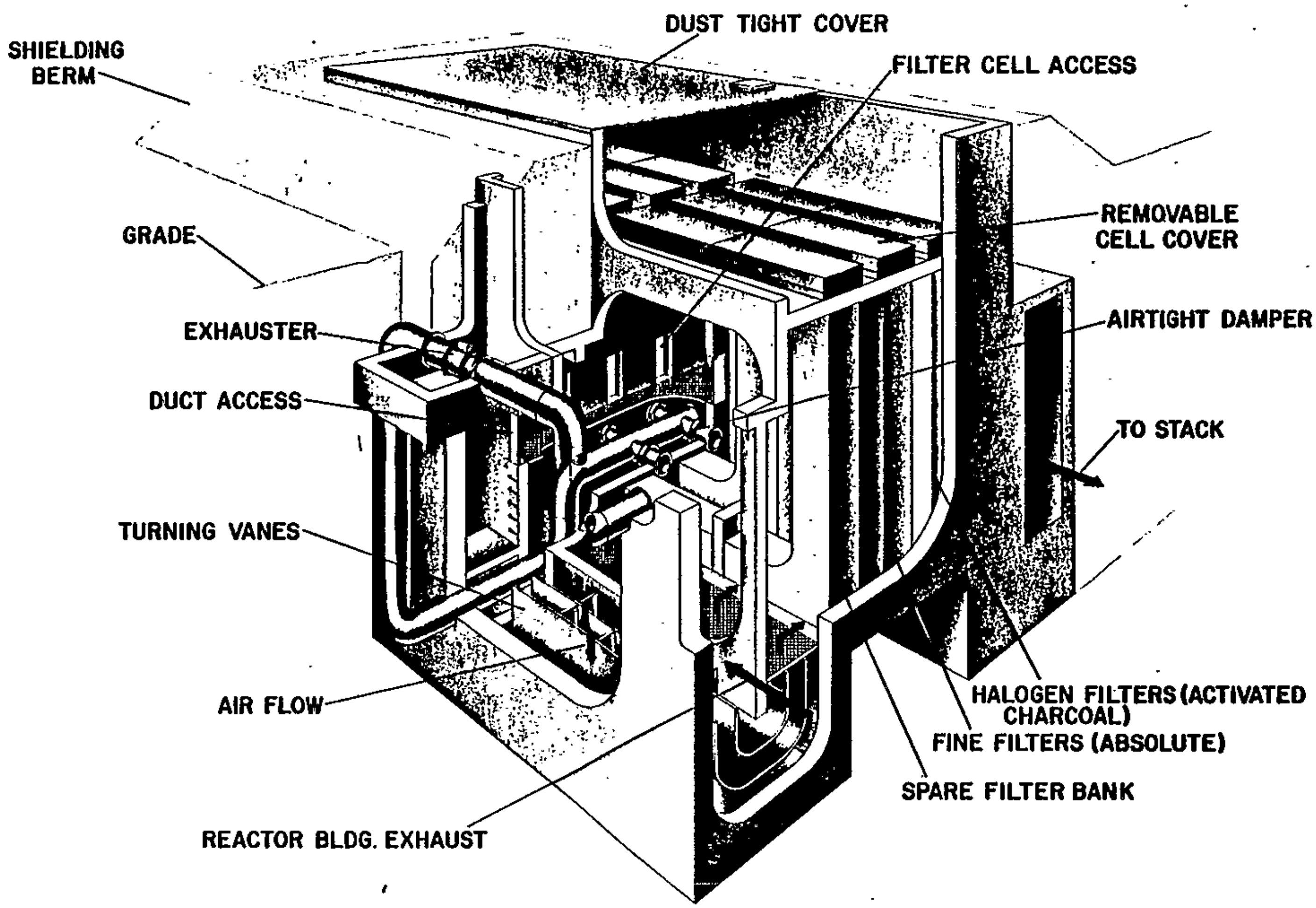

FIGURE X-6

Reactor Confinement Filter Building

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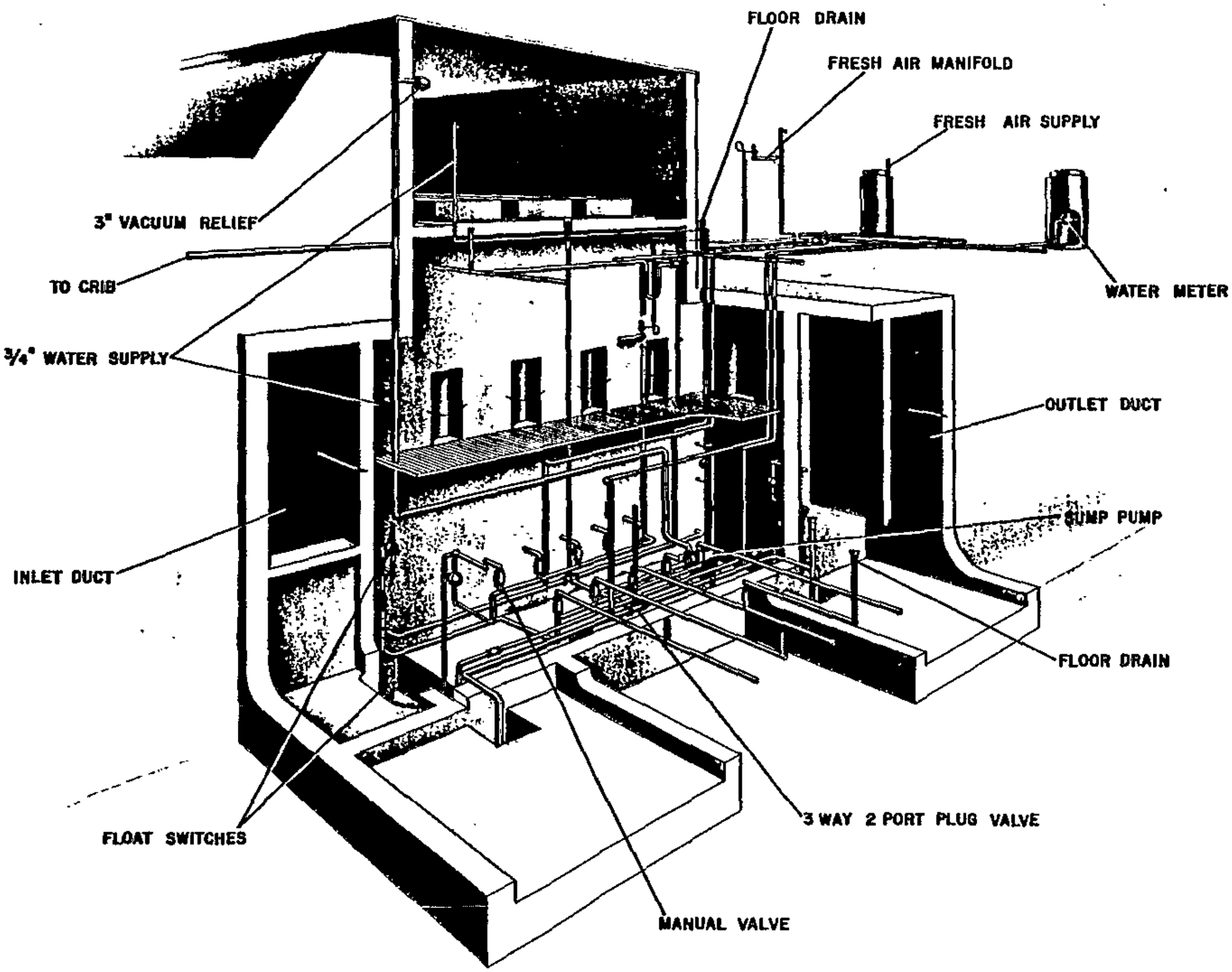

FIGURE X-7

Reactor Confinement Filter Building Piping Arrangement

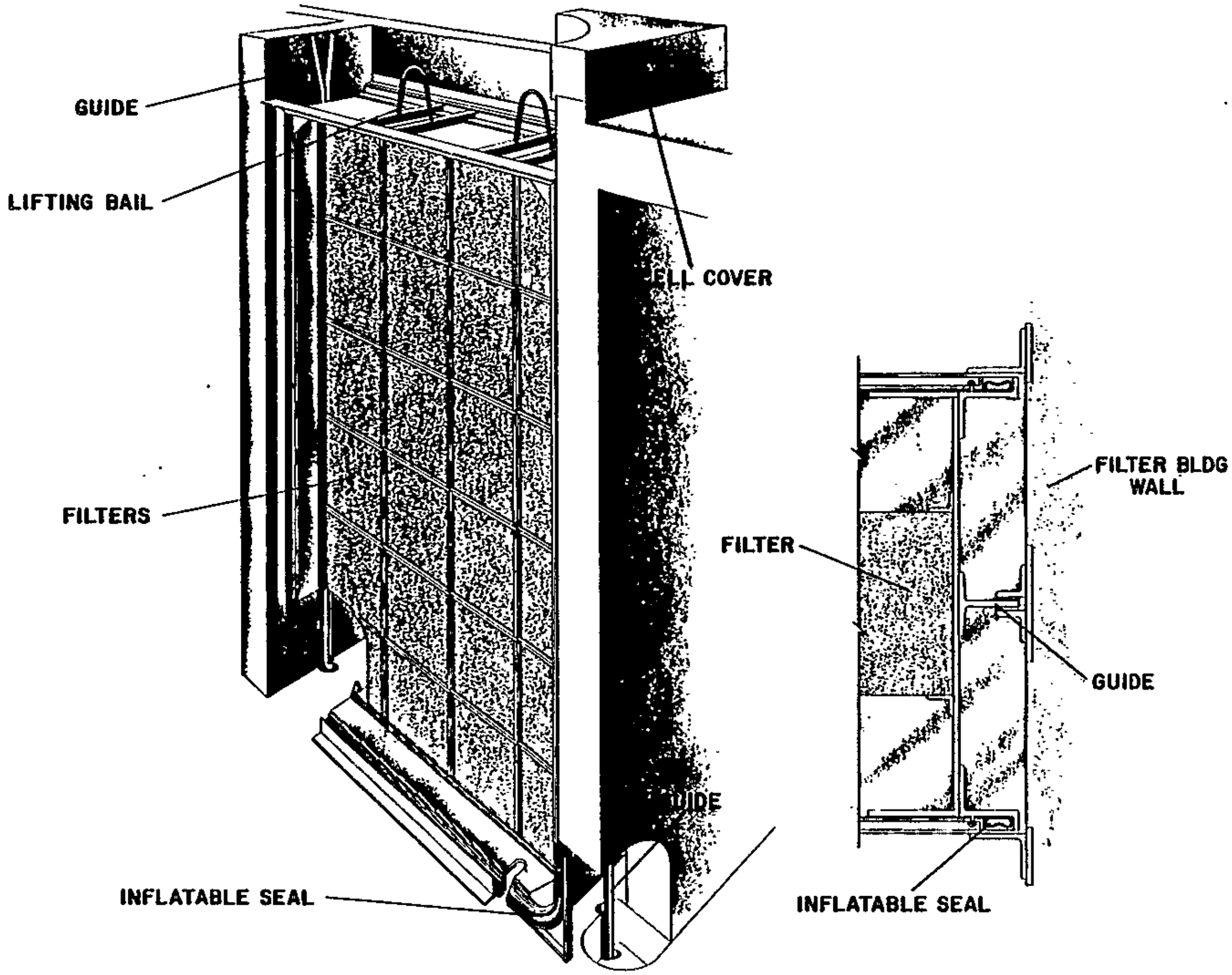

FIGURE X-8

Typical Filter Bank Arrangement

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slot formed by aluminum inserts fastened to the concrete walls of the filter building. When the frame is in place, a continuous neoprene seal, which circles the frame, is inflated until a seal is made between the frame and the aluminum inserts embedded in the cell walls. Seals are provided on the upstream and downstream side of the filter frame. Removal of the frame is accomplished by deflating the seals and lifting it out of the building with a mobile crane.

The individual filters are installed in the aluminum filter frames and bolted in the frame with a retaining flange, until a sponge neoprene gasket between the filter and the filter frame is compressed. This forms an air-tight seal around the filter.

There are thirty-two filters in a frame with four frames to a filter bank. There are 144 filters per bank in a 117 Filter Building.

There are two filter banks in series. The first is a particulate bank, which removes the particulate matter from the air stream. This filter is rated as 99.95 percent efficient in removing 0.3 micron dioctylphthalate particles. The filter core consists of impregnated mineral fiber separators and glass fiber web strips. It is fabricated by folding a continuous strip of fiber web back and forth over corrugated separators. The core is placed in a plywood frame and sealed at the top, bottom, and sides with a self-extinguishing rubber-type cement. Neoprene gaskets are glued on the frame edges of the filter. The filters are fire and water resistant and have a capacity when clean of 1000 cfm at 1-inch water gage differential pressure.

The second filter bank is an activated charcoal bank, which contains a 1-inch bed of activated coconut charcoal. The charcoal is held between two horizontal, accordian pleated, perforated steel plates and measures 24 by 24 by 8-3/4 inches, and is rated for 1000 cfs at 0.65 inches water gage differential pressure. These filters remove the halogen vapors in the air stream. Tests show that the charcoal filters will remove more than 95 percent of the iodine from an air stream.

The filter cells in the building can be isolated from the exhaust system by filling the seal pits on the inlet and outlet side of the cell with water. The water piping system provided in the building serves as both the fill and drain lines for the seal pits. Extension handles are provided for the valves so that they can be operated from the cell deck of the building. Water to fill the seal pits is supplied from the 105 Building filtered water system. The water is measured by water meters to prevent flooding the filter cells. In addition, level indicators are provided and are annunciated. A 200 gpm pump is provided for emptying the seal pits. The seal pit drain water is pumped to the contaminated collection basin at the rear of the reactor building which in turn drains to the radioactive water sewer crib in the area.

The control of the seal pit pump is at the upper floor level. Low level indicators with electrical contacts are provided in the seal pits which automatically shut off the pump when the pits are empty.

Floor drains have been installed in the upper and lower floors for decontamination. These drains discharge into a common inlet seal pit, where the water is pumped to the contaminated collection basin.

An exhaust system of 7000 cfm capacity is provided in the building. This system provides a positive flow of air into the filter cells from the atmosphere when the cells are opened for contamination control. There are two intakes into each filter cell. These intakes are opened and closed by butterfly valves. The discharge of the exhaust system is into the inlet plenum of the filter building.

E. Instrumentation

An engineering flow diagram of the instrumentation provided for the confinement system is shown in Figure X-9. In the 105 Building, the ventilation air pressure at the rear face, the inner rod room, at the top of reactor, at the work area, and at the X-levels is measured and compared with the atmospheric air pressure outside. If the air pressures in these building spaces are not within the preset range, they are annunciated in the Reactor Control Room. Doors can then be closed or the ventilation balance in the 105 Building readjusted to bring the pressure back in the preset range.

The exhaust air sampler, which activates the fog spray system, is a scintillation detector which continuously monitors the reactor building exhaust air flow for the presence of radio-iodine. The equipment is located in the Sample Room which is located over the inlet and outlet ducts of the filter building. The exhaust air sample for the system is taken from a sample probe in the inlet duct below. The scintillation detector system activates the fog spray system and is annunciated in the 105 Building Control Room.

The next two instrument systems are also located in the Sample Room and continuously monitor and measure the radiation level of air borne particulate matter in the exhaust air before and after the filter banks. Air samples are taken from the inlet and outlet ducts and forced through continuous moving filter paper strips where the particulate matter is removed. The radiation level of the section of filter paper is then counted with a Geiger-Mueller tube detector system. High readings of the particulate samplers are annunciated in the 105 Building Control Room.

The radio-iodine concentration in the exhaust air downstream of the filter banks is monitored and measured. The air sample from the particulate sampler monitoring the outlet duct is passed through an activated charcoal bed. The radio-iodine on the charcoal bed is then measured with a scintillation counter. High reading of the charcoal sampler is annunciated in the 105 Building Control Room.

The buildup of radioactive material on the filters is monitored by standard Health Monitoring Chambers inserted into thimbles in the filter cells. The signals from the chambers are read by amplifiers in the Sample Room. High readings are annunciated in the 105 Building Control Room.

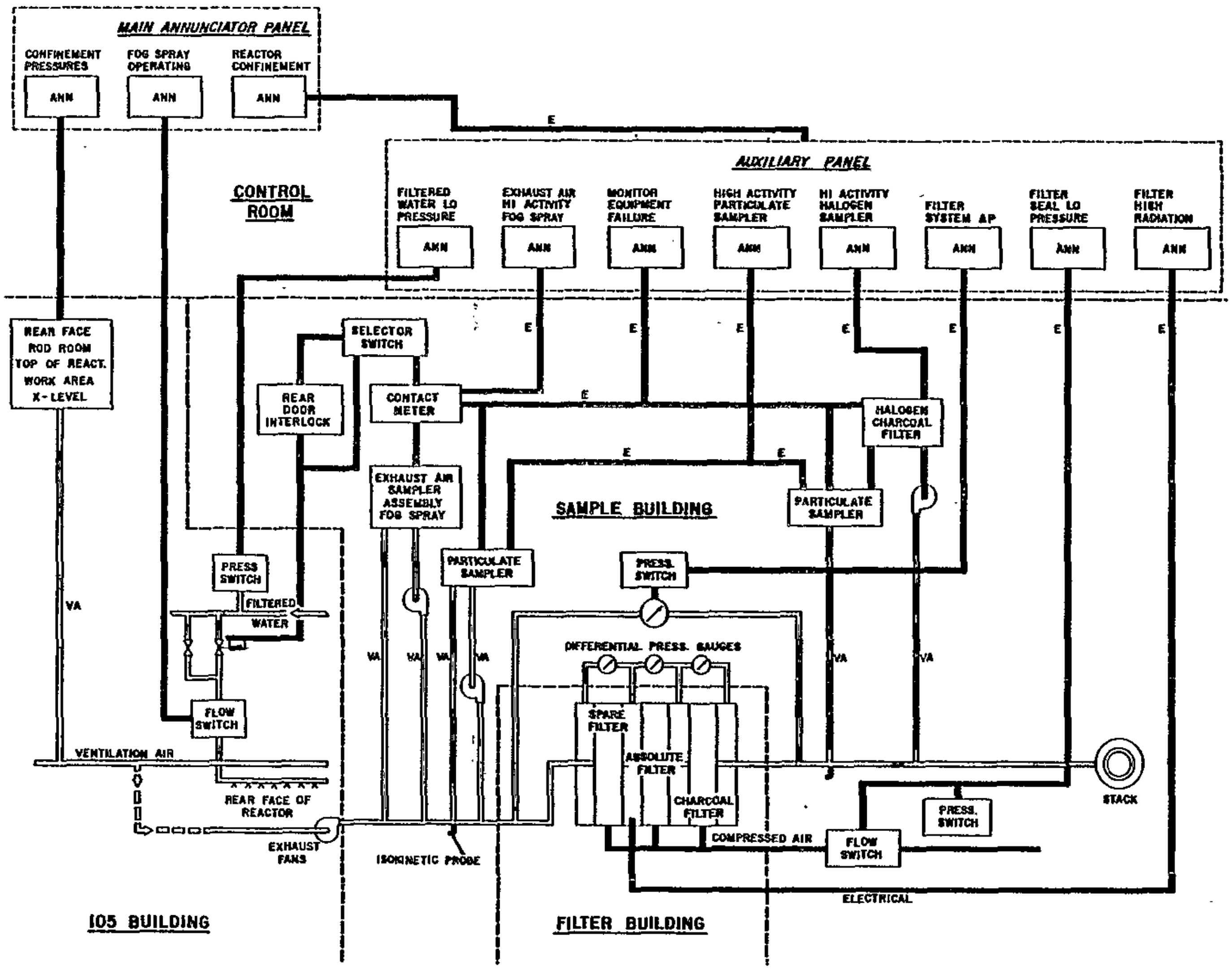

FIGURE X-9

Instrument Engineering Flow Diagram

Failure of the radiation instrumentation equipment located in the Sample Room is also annunciated in the 105 Building Control Room.

In addition to the above radiation instrumentation, the differential pressure across the individual filter banks and the over-all filter system are indicated in the Sample Room. Over or under pressure readings of the over-all filter system is annunciated in the 105 Building Control Room.

Instrumentation is available to monitor the compressed air supply system for the filter frame seals and indicate the air pressure in each filter frame seal. The compressed air supply system can supply a maximum of 5 scfm of air to any seal or seals which may be leaking. If this supply of air cannot maintain the minimum pressure in the leaking seal the condition is annunciated in the 105 Building Control Room.

XI. IN-REACTOR EXPERIMENTAL FACILITIES

With the exception of a shield test facility in the top shielding of the DR Reactor, all test channels at the B, C, D, DR, F and H Reactors are located at the right (far) side of the reactor. Side test holes are located in each reactor, and in general are formed by step plug penetrations through the reactor biological and thermal shielding to a square horizontal channel created by the absence of a column of graphite filler blocks in a filler layer of the graphite stack. At the B, D, and F Reactors some of the test holes were formed by inserting special filler blocks, through which one and one-fourth inch diameter channels were bored, to provide smaller round test channels. The test channels extend only into the core of the reactor at the B, D, DR, and F Reactors. Three H Reactor test channels and all but two in the C Reactor extend entirely through the graphite moderator stack, with access to the channel provided by step plug shielding on the left (near) side. The test channels are used for irradiating whole graphite blocks or smaller samples of graphite or other high melting materials which have been quartz-encapsulated in graphite holders, and as the means by which specially designed water-cooled sample irradiation facilities and recirculating coolant test loops can be located in-reactor. Also, some test channels are now used for locating in-reactor, the detectors of nuclear instrumentation such as the sub-critical monitor.

Shielding test facilities are located at the DR Reactor, as noted above, and at the C Reactor. The facility at DR Reactor consists of removable biological shielding blocks. Test shielding material can be substituted from some or all blocks, for subsequent radiation attenuation measurements. The C Reactor shield test facility is located at the right side of the reactor, and consists of a removable stepped section of the biological shield. Pre-formed test shielding sections can be positioned in the several step compartments.

Experimental equipment and instrumentation, for controlling and recording test conditions in-reactor, are located in rooms located on the far side of the reactors (the X-Levels).

The general location and arrangement of test facilities at the reactors are shown in Figures XI-4 through XI-8.

A. H-1 Loop

The H-1 loop is high-temperature, high-pressure, recirculating water facility with a test section located in the "A" test hole on the X-1 level of the H Reactor. The loop is operated in support of the Aluminum Corrosion and Alloy Development Program sponsored by the AEC's Division of Reactor Development. Recent modifications have been made to improve control by the installation of remotely operated valves and the necessary instrumentation to automatically control cooling water flow and temperature. Figure XI-1 is a schematic diagram of the major loop components.

The loop safety circuits which are connected to the H Reactor safety circuits trip on either two-out-of-three independent temperature signals or two-out-of-three independent flow signals.

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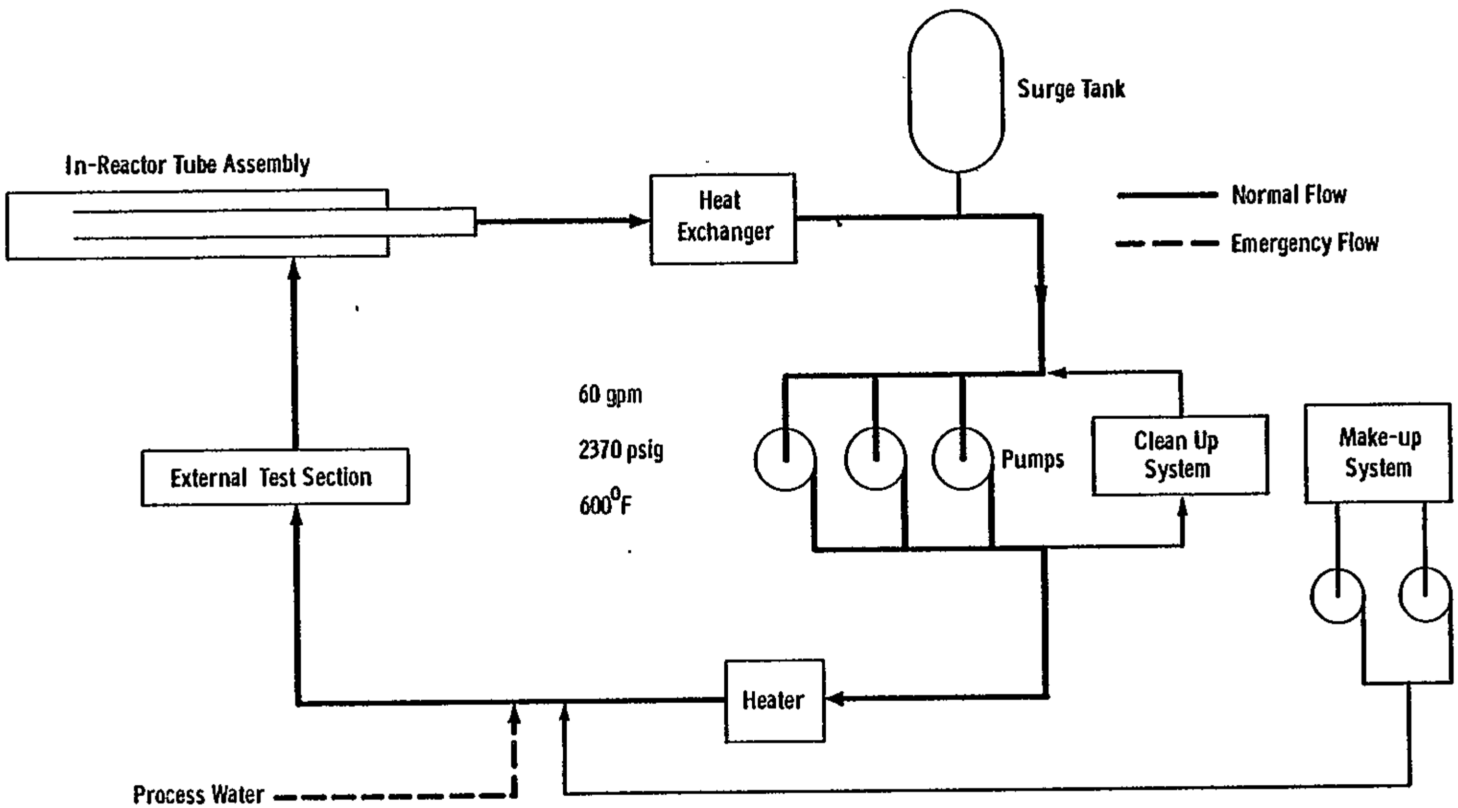

FIGURE XI-1

H-1 Loop

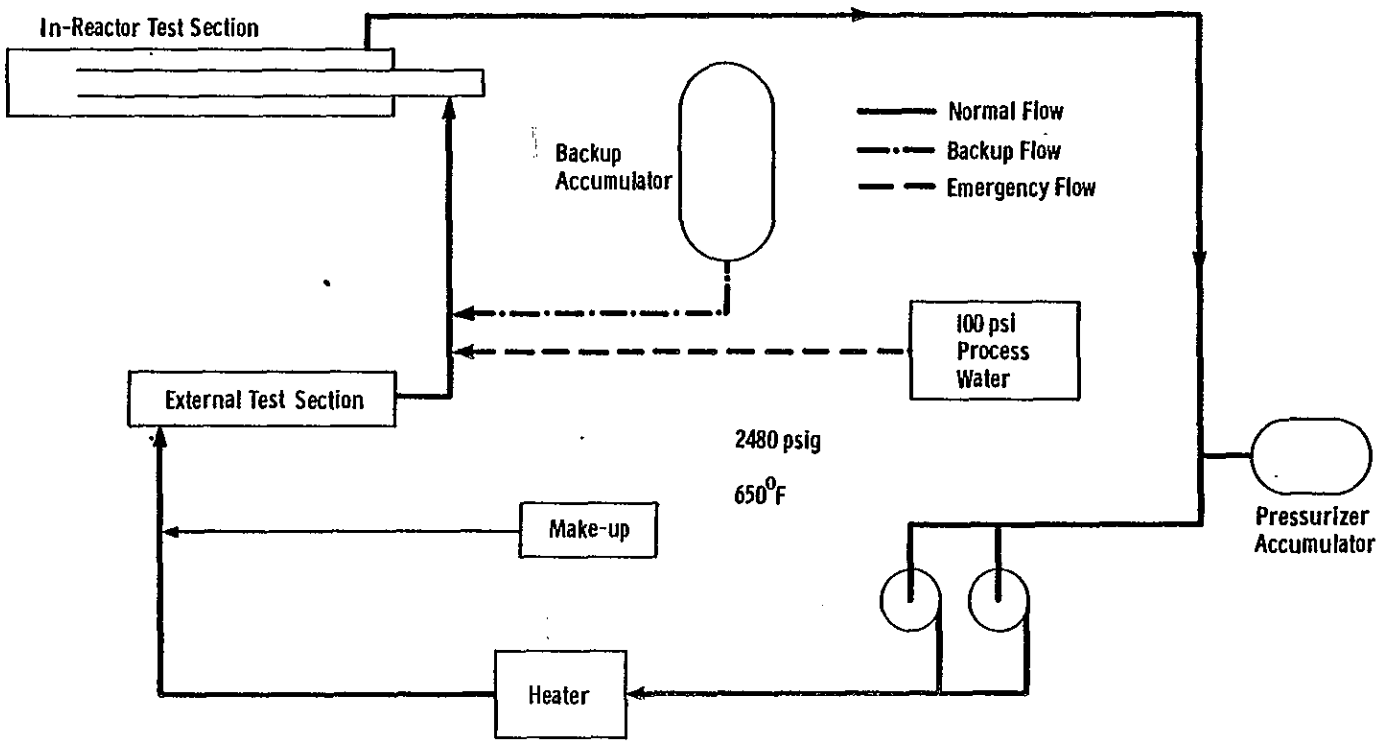

FIGURE XI-2

C-1 Loop

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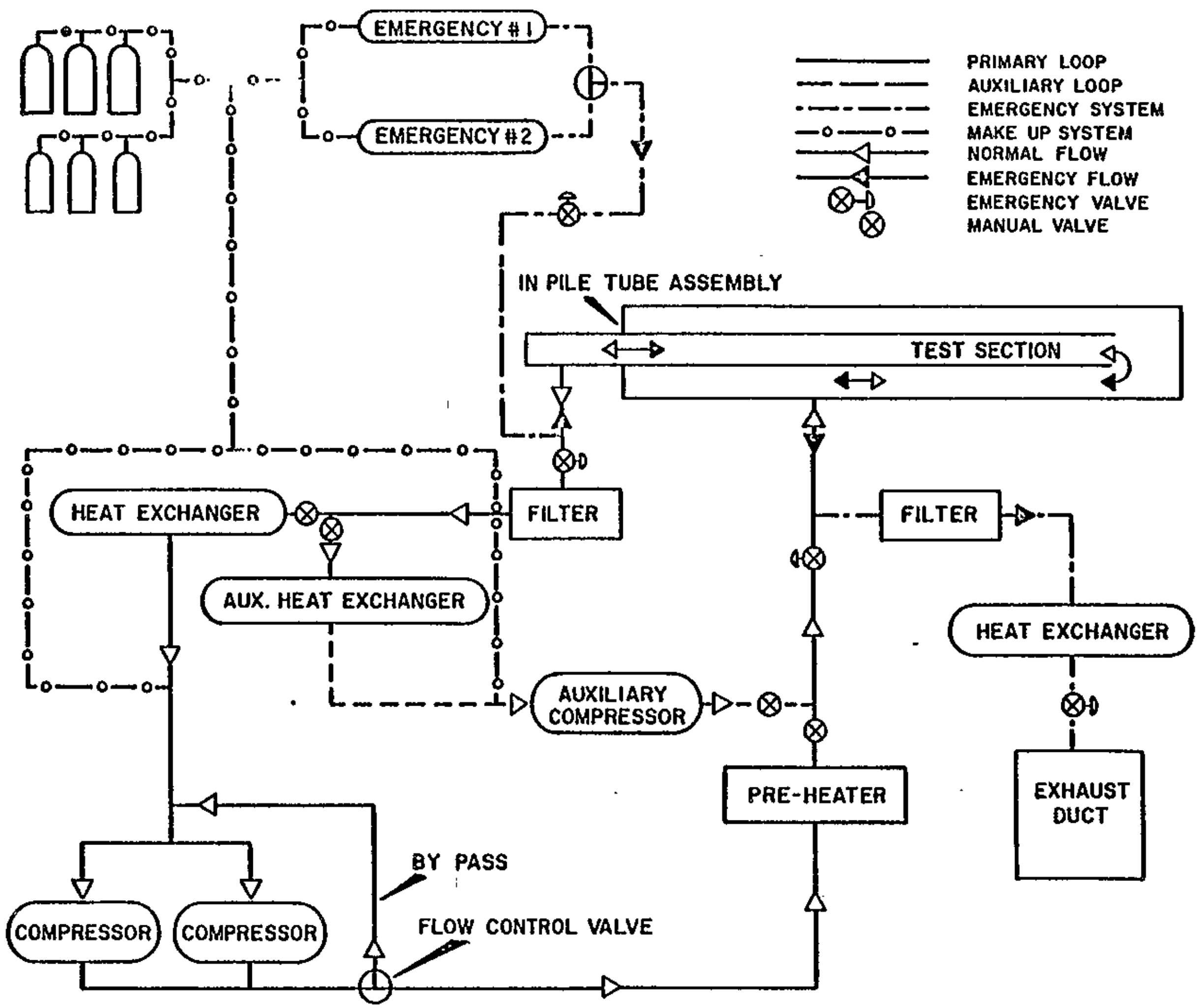

FIGURE XI-3

DR-1 Loop

When cooling water recirculation cannot be maintained, a single-pass emergency system using deionized water is used, since corrosion tests require rigid control of water quality at all times. Should the deionized water supply be exhausted, normal reactor cooling water is used to assure coolant flow continuity.

B. <u>C-1 Loop</u>

The C-1 loop, to be located in the test hole of the C Reactor, is designed as a high-temperature, high-pressure, recirculating cooling water facility for the irradiation of non-fissionable metallic samples. It is designed to operate at 2480 psig and 650 F. Figure XI-2 is a schematic diagram of the major components of this facility which are the primary loop, the backup accumulator, and the emergency process water supply. It is intended that only a low coolant flow trip will be incorporated into the reactor safety circuit system. Other off-standard conditions of temperature, pressure, flow, and radiation will actuate audible alarms in the control room.

C. <u>DR-1 Gas Loop</u>

The DR-1 Gas Loop is a gas-cooled test facility installed in the test hole of the DR Reactor. The purpose of the loop is to provide a test facility for the evaluation of gas-cooled reactor components, primarily fuel elements.

The facility was designed for operation with either nitrogen or helium gas as the coolant at a maximum pressure of 215 psig. The principal parts are: two recirculating loops; a stored-gas, one-pass emergency cooling system; and an in-reactor tube assembly as indicated in Figure XI-3.

The in-reactor tube assembly consists of two concentric tubes approximately twenty-five feet long. The in-reactor end of the outer tube is sealed. During normal operation, coolant gas enters the annulus and returns through the center tube in which the test specimen is installed. The outer, pressure-bearing tube is constructed of Inconel, with a maximum permissible operating temperature of 1275 F.

The loop instrumentation provides equipment for indicating and recording pressure, coolant flow, temperature and electrical data for the loop components and the test specimen. Certain instruments include alarms that indicate off-standard conditions, and automatically scram the reactor when these conditions reach pre-determined values. These are: low water flow in the heat exchanger, low gas flow in the loop, loss of power to the compressors, low gas pressure in the loop, low compressed air supply, high pressure drop in the test section, and high radiation level.

Two gross-gamma monitors are located in the reactor area to follow the radiation level in the vicinity of the loop piping. Primarily this instrumentation provides indication of fission product contamination of the coolant gas.

All alarms are annunciated and also indicate on an alarm panel by individual lights. The bypass of any loop scram connection and the operation of the loop scram relay is indicated individually in the reactor control room.

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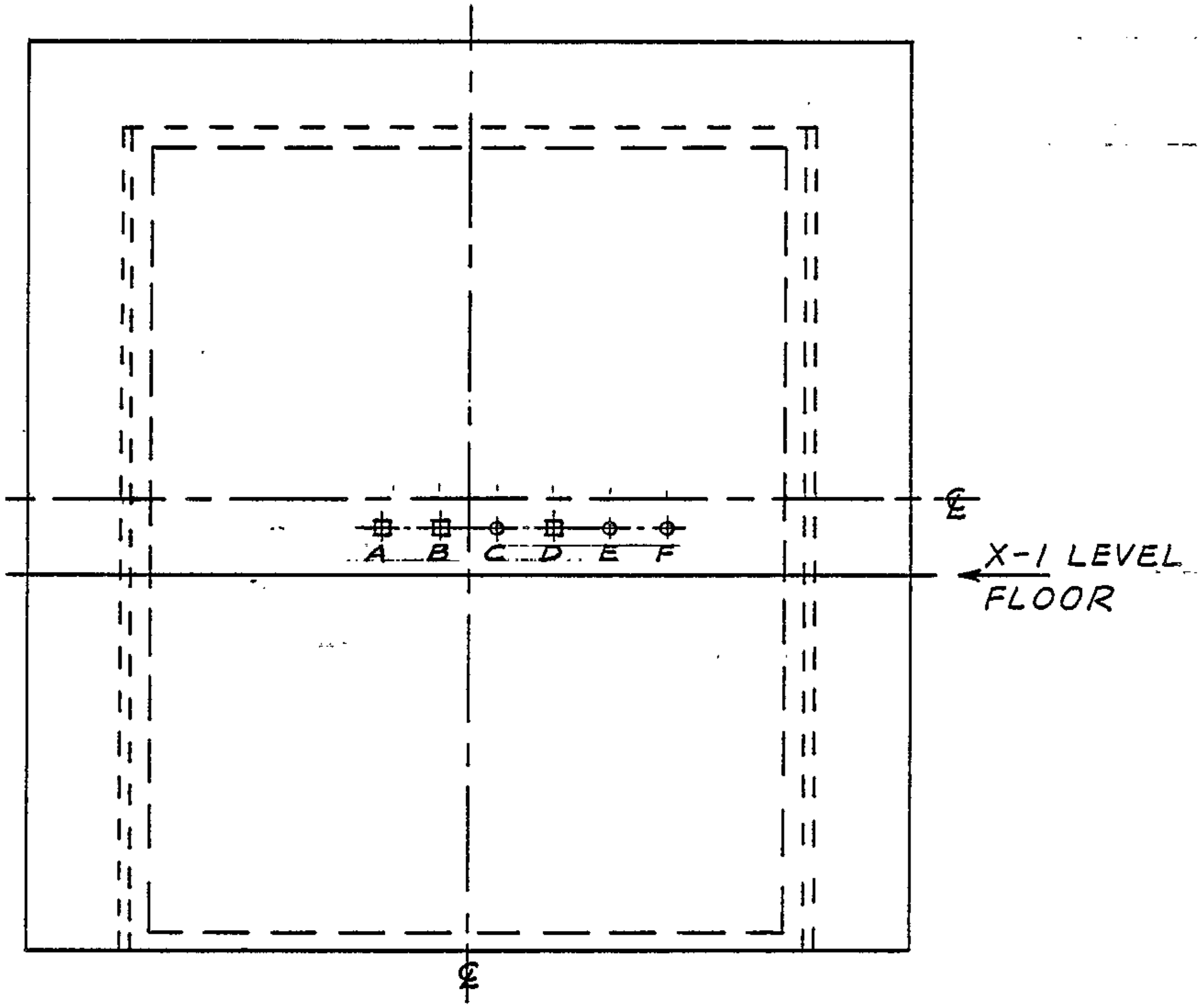

FIGURE XI-4

General Arrangement of Test Holes, Far Side of B, D, and F Reactors

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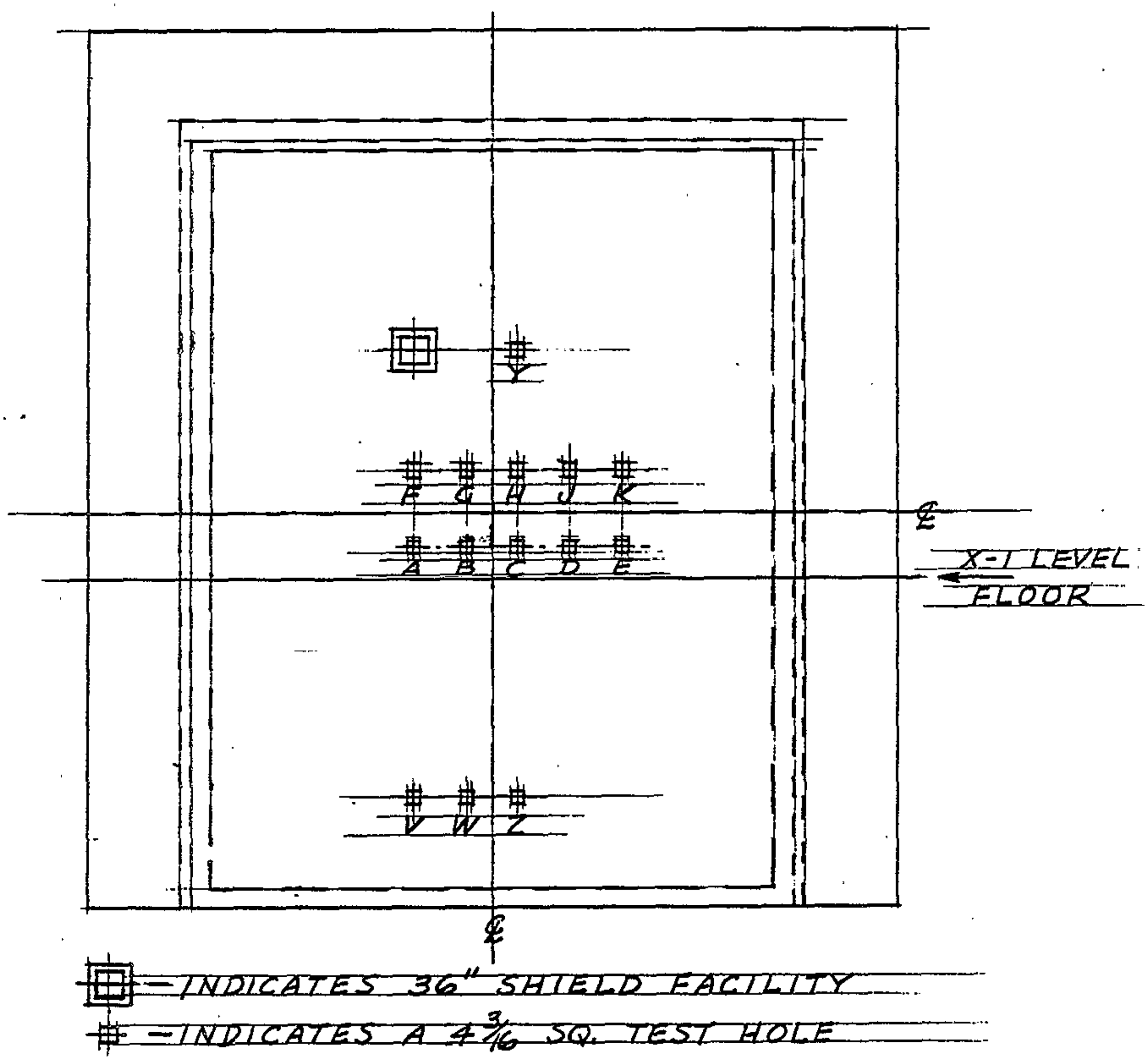
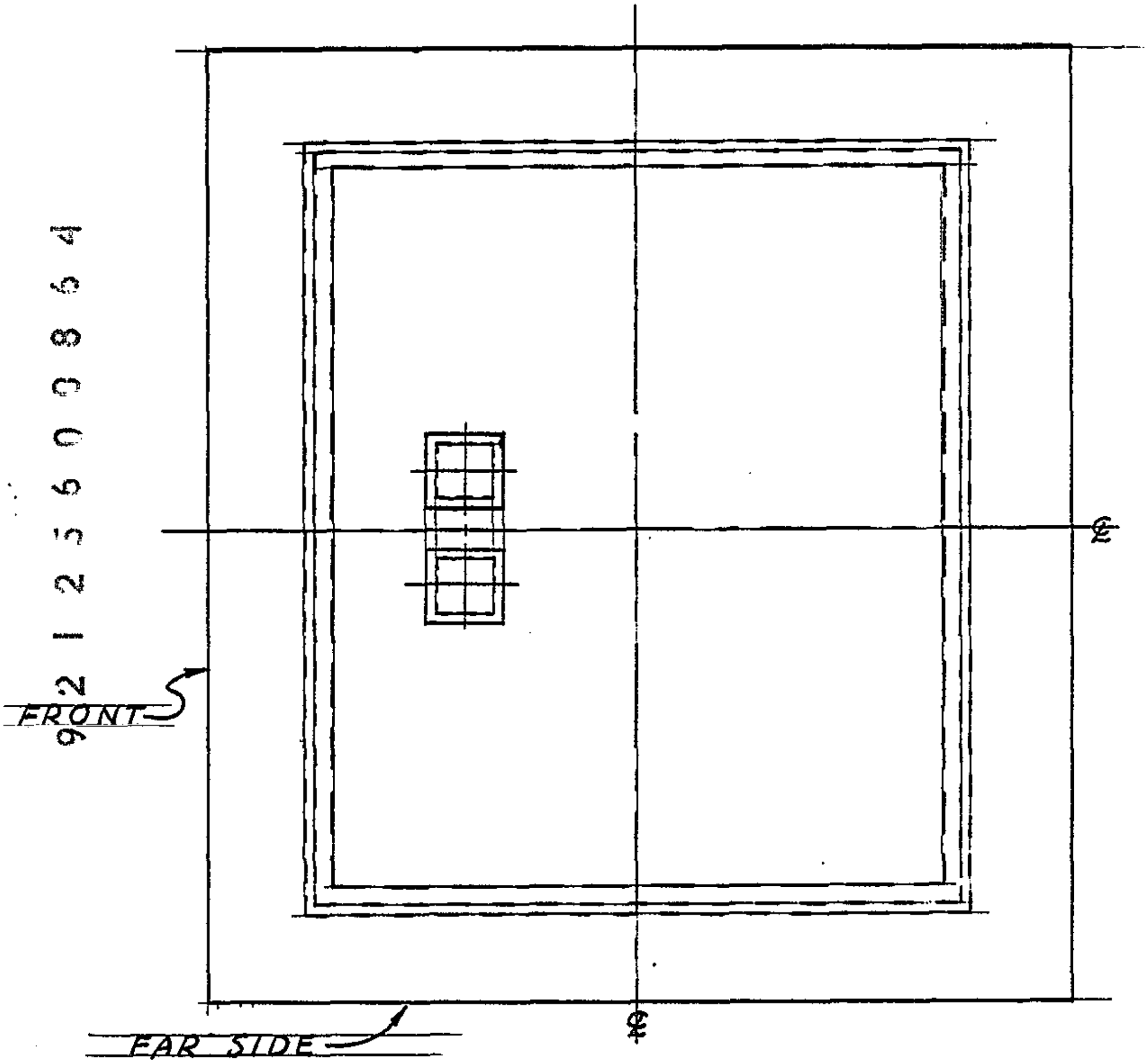


FIGURE XI-5

General Arrangement of Test Holes, Far Side of C Reactor



— INDICATES TEST WELL 41½ SQ. TOP x 35⅜ SQ. BOTTOM x 50 DEEP (STEPPED)

FIGURE XI-6
General Arrangement of Test Holes, Top Side of DR Reactor

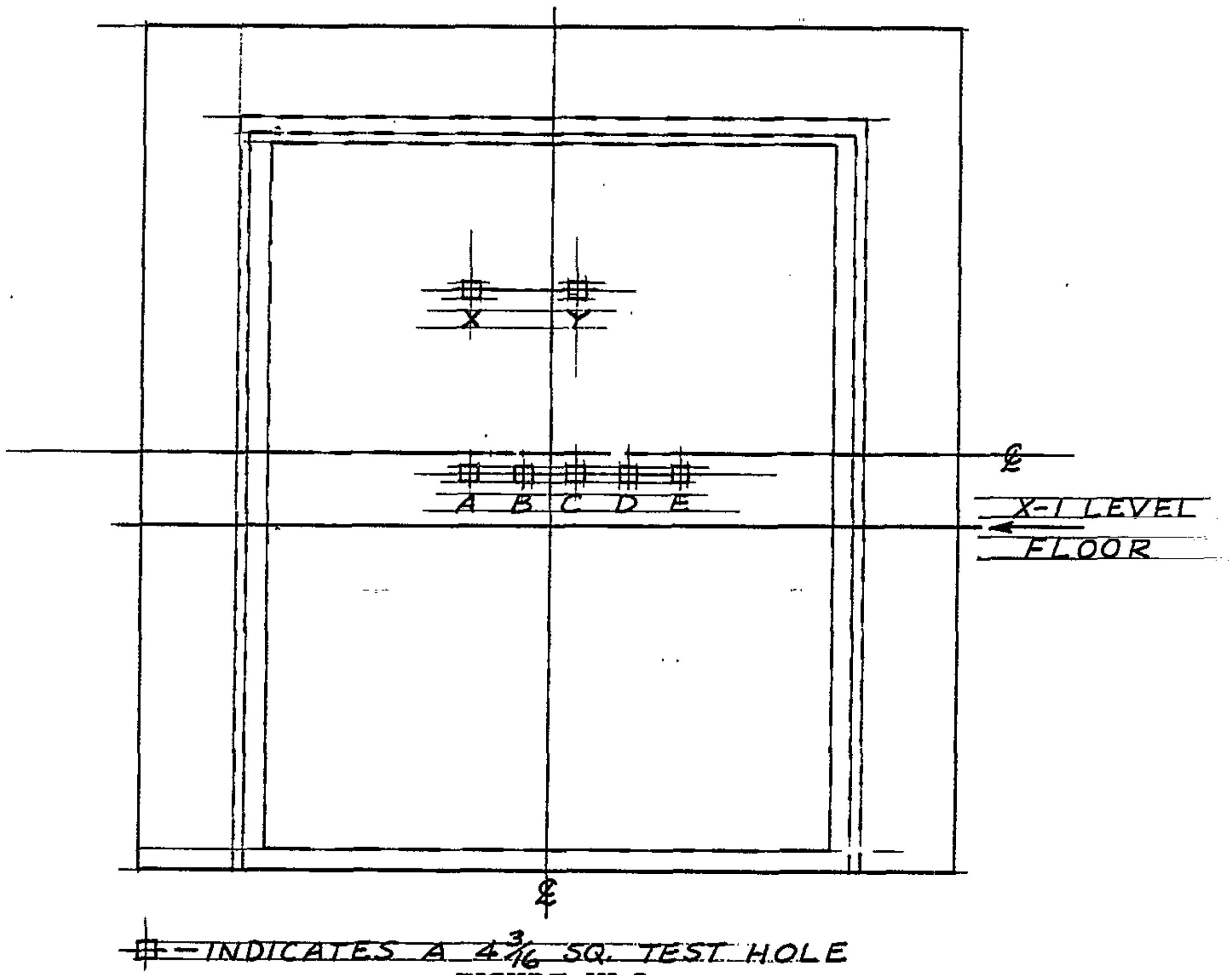


FIGURE XI-7

General Arrangement of Test Holes, Far Side of DR Reactor

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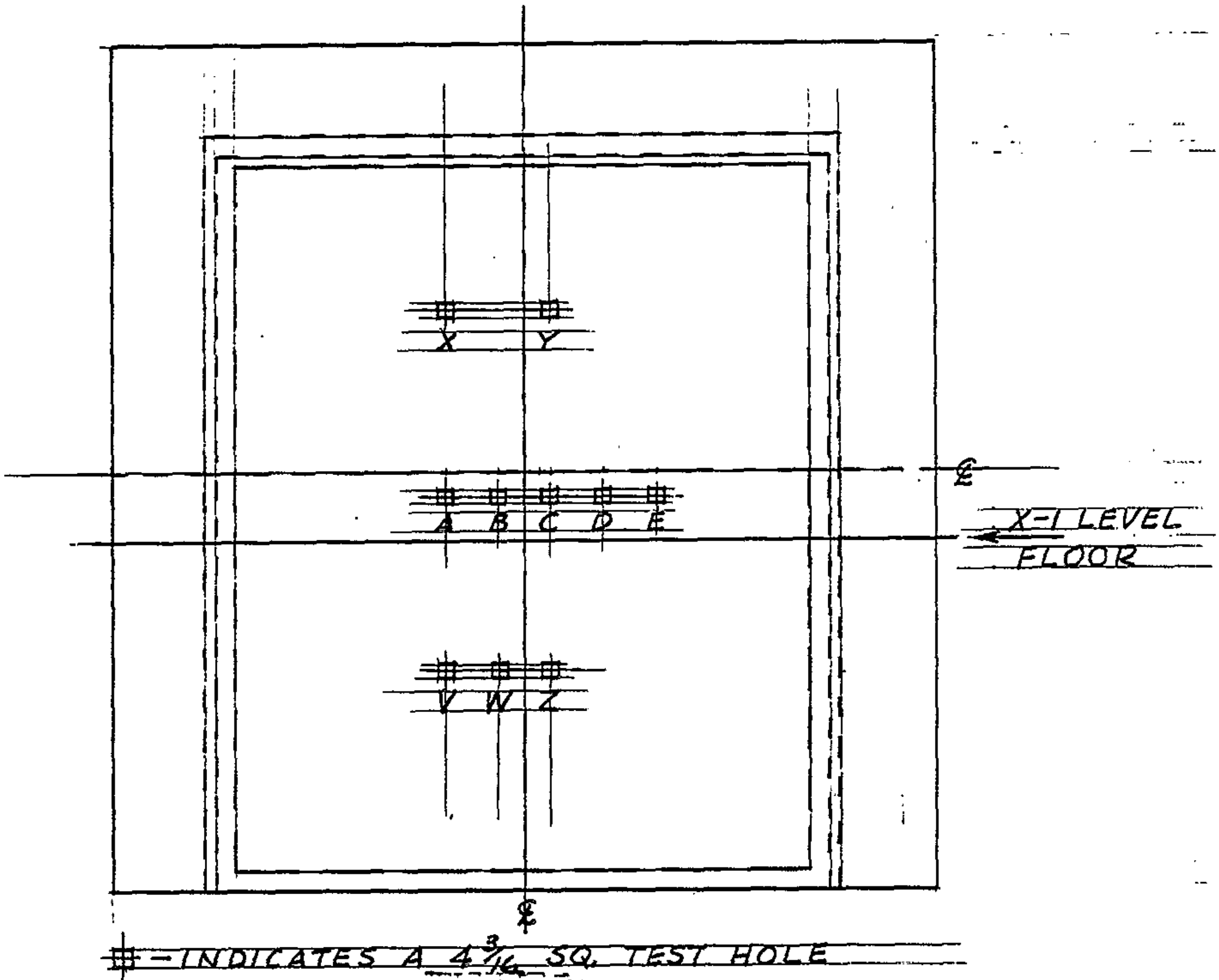

FIGURE XI-8

General Arrangement of Test Holes, Far Side of H Reactor

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